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Final Report and Reference Guide documenting currently available predetermined time systems evaluated as to their ability to meet MIL STD 1567A. Identified for evaluation were 20 predetermined time systems, two machining data systems, and three software systems which utilize commercially available predetermined time systems. Report includes a detailed description of each system identified and where applicable, a statistical evaluation of the system's accuracy. System descriptions include history, general description, application method, training information, costs, compliance to MIL STD 1567A, strengths and weaknesses, and current users.

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AIR FORCE BUSINESS
RESEARCH MANAGEMENT CENTER

MANUFACTURING WORK MEASUREMENT SYSTEM EVALUATION

FINAL REPORT AND REFERENCE GUIDE

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

PREPARED BY: ARTHUR YOUNG & CO.
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KANSAS CITY, MO 64105

CONTRACT NO. F33615-86-C-5066

APRIL 1987

Arthur Young

A MEMBER OF ARTHUR YOUNG INTERNATIONAL

PREFACE

This reference guide has been prepared to provide its users with a basic understanding of work measurement, the intent of MIL STD 1567A, and an explanation of currently available predetermined time measurement systems, their application, and potential to meet MIL STD 1567A.

The data contained in this report/reference guide does not represent the author's opinion but is based on data provided by system vendors and user references supplied by the vendors.

CERTIFICATION OF TECHNICAL DATA CONFORMITY

The Contractor, Arthur Young & Company, hereby certifies that, to the best of its knowledge and belief the technical data delivered herewith under Contract No. F33615-86-C-5066 is complete, accurate, and complies with all requirements of the contract.

4/7/87
Date

James H. Bennett, Principal, Tulsa Office
Name and Title of Certifying Official

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I. EXECUTIVE SUMMARY

A. BACKGROUND OF STUDY

Approximately eight years after the Department of Defense had installed their Cost Schedule Control System, the United States Air Force released a criteria-based performance-measurement system commonly known as MIL STD 1567A. In summary, this standard required that contractors maintain a documented work measurement program which is technically applicable to acquisition programs that exceed $100 million and production programs that exceed $20 million annually.

Although the system was basically designed to require contractors to develop and maintain fabrication and assembly operations standards, it also requires that appropriate reporting be in place in order to provide variance analyses and an appropriate audit trail.

Although subjectivity can come into play among contractors during the installation of MIL STD 1567A, the following major requirements are specified in the standard:

- Type I standards representing 80% coverage of all touch labor are to be established, using a recognized and accurate technique to reflect an accuracy level of ±10% at a 90% confidence at the operational level.

- Performance reports must be prepared and variance reports published for significant deviations.

- A formal audit program must be established and implemented.

To be in compliance, a contractor must utilize such recognized techniques as time study, standard data, or predetermined time systems. While most contractors are familiar with time study and standard data, much confusion surrounds the selection and application of the most appropriate predetermined

time system for their particular environment. This lack of understanding and limited source documentation has created discrepancies in their approach, created unnecessary validation of system data, and hindered acceptance, resulting in unnecessary implementation costs.

With this in mind, the United States Air Force contracted with Arthur Young & Company to perform an in-depth review of currently available predetermined time measurement systems and to compile this data into a single reference document which could be used by defense contractors in constructing and evaluating work measurement systems in accordance with MIL STD 1567A.

B. OBJECTIVES

The primary objective of the study was to identify and evaluate currently available predetermined time systems which would result in the following:

- A single source reference document to be used in constructing and evaluating work measurement systems which meet MIL STD 1567A.
- Reduced duplication of evaluation efforts and implementation costs.
- Improved contractor understanding of available predetermined time systems.

Our technical approach was based directly on our understanding of the study objectives and requirements, and on having used a variety of predetermined time systems during the implementation of work measurement programs.

Our approach used to review, analyze and evaluate currently available predetermined time systems was tailored specifically to the unique requirements of the United Stated Air Force and MIL STD 1567A, yet based on sound industrial engineering/work measurement principles. This approach is explained in detail in this report's section entitled "Technical Approach."

C. STUDY FINDINGS

During the study, 14 system vendors and 20 commercially available, predetermined time systems were evaluated. In addition, two systems were evaluated which provide machining standards, and three software systems were evaluated which utilize commercially available, predetermined time systems.

Validation documentation, provided by each system vendor, was used to evaluate the system's accuracy and its ability to be used by Defense Contractors to implement a work measurement program in compliance with MIL STD 1567A. In addition to or in place of validation documentation, comparisons of the vendor's system to time studies and/or other predetermined time systems, provided by the vendor, were used. To test the accuracy, a statistical analysis using the student's "t" test for matched-pair observations was performed and accumulated system accuracy was determined by utilizing the following equation:

$$\sigma = \sqrt{.05^2 + (x)^2}$$

Where σ = accumulated accuracy

.05 = absolute variance from MTM-1

x = absolute variance (in %) of the reviewed system

Many of the systems reviewed compared themselves to MTM-1 analyses. Based on the MTM-1 tested accuracy of ±5% at a 95% confidence level, the accumulated system accuracy for those systems compared to MTM-1 are shown on Table 1.0 on the following page.

TABLE 1.0 ACCUMULATED SYSTEM ACCURACY BY SYSTEM

SYSTEM	SYSTEM ACCURACY VARIANCE TO MTM-1	NET ACCUMULATED SYSTEM ACCURACY
MTM-2	0.23%	5.0%
MTM-3	0.36%	5.0%
MTM-MEK	3.20%	5.94%
MTM-UAS	1.26%	5.16%
MTM-TE	1.77%	5.30%
MTS	5.08%	7.12%
MANPRO	6.68%	8.34%
CUE	2.62%	5.64%
MSD	0.75%	5.06%
UNIVEL	0.42%	5.02%
MODAPTS	5.90%	7.73%
WORK-FACTOR	18.75%	19.40%

In summary, 19 of the 22 predetermined time systems evaluated were able to be validated. Those systems unable to be validated are as follows:

- GE Standard Data
- Elemental Standard Data (NAVAIR)
- Metcut Machining Data

During our evaluation of the Work-Factor® system, data provided by the vendor demonstrated that the system provided values consistently less than MTM-1 and leveled time studies. The overall deviation was 18.75% and 19.47% less when compared to MTM-1 and time study, respectively. Based on this data, it was determined that appropriate leveling would be required to develop standards which would be in compliance with MIL STD 1567A.

As it relates to the three software systems, their ability to meet the accuracy requirements set forth in MIL STD 1567A is directly dependent on the predetermined time system used.

A chart summarizing each system evaluated was prepared and divided into two sections. The first section evaluated the systems against criteria outlined in Paragraph 5.1 of MIL STD 1567A while the second section evaluated the systems against basic system criteria.

D. CONCLUSIONS AND RECOMMENDATIONS

Based on this study, it was concluded that a sufficient number of predetermined time systems are available and can be used by Defense Contractors in implementing a work measurement program which will meet the requirements set forth in MIL STD 1567A. In addition, based on discussions with system vendors and system users, it appears that a number of Defense Contractors have implemented or are in the process of implementing, work measurement programs in compliance with MIL STD 1567A. In selected instances, these discussions revealed that some Defense Contractors have passed Government audits in relation to MIL STD 1567A.

In summary, the following conclusions were realized based on the results of this study:

- Majority of the predetermined time systems evaluated could be used by Defense Contractors to implement a work measurement program in compliance with the MIL STD 1567A as identified in Paragraph 5.1.

- Accuracy requirements, as stated in Paragraph 5.1 of the MIL STD, place the ability to meet this requirement on the application of the system and the final product or Type I standard and not on the system itself.

- Accuracy of the Type I standard derived from using one of the systems verified during the study will directly depend upon the accuracy of the system applicator.

- For those systems in which their theoretical accuracy was unable to be verified, the potential does exist that, if the system is properly applied, resulting standards may meet accuracy requirements for Type I engineered labor standards.

- As the burden of selecting and implementing a work measurement program is the responsibility of the Defense Contractor, it is believed that this reference guide will provide a useful resource for identifying and selecting an appropriate work measurement system.

Based on this study, a number of recommendations were developed as follows:

- The United States Air Force should consider performing an evaluation of applicator accuracy achieved when applying those predetermined time systems identified in the study during the development of Type I standards. Consistency in application will be a key factor in developing standards in compliance with MIL STD 1567A.

- The United States Air Force should recommend that Defense Contractors not only evaluate and select systems based on their projected level of accuracy, but that they should also consider the following:

    - System Application Method
    - System Flexibility
    - Training and Certification Requirements
    - System Maintenance and Support
    - System/Implementation Costs
    - Implementation Time Requirements

- The United States Air Force should consider sponsoring a joint defense-contractor/system-vendor seminar in which the study team presents the study findings and Contractors are invited to ask questions and express concerns relating to MIL STD 1567A.

In summary, the results of this study have provided the United States Air Force with a comprehensive Reference Guide to be provided to Defense Contractors and to be used as a guide to evaluate and select those systems which best fit their needs in implementing a work measurement program. Having been developed to present an overview of each available predetermined time system, the Reference Guide will provide a useful starting point and tool for identifying appropriate predetermined time systems.

II. TECHNICAL APPROACH

The technical approach used to review, analyze and evaluate currently available predetermined time systems involved a single phase with seven major tasks. A detailed outline of the technical approach used is discussed in the following paragraphs.

Phase I - Evaluate Predetermined Time Systems and Develop Reference Guide

During this single phased study, the project team identified, evaluated and documented in a reference guide, all currently available, predetermined time systems which were found to meet MIL STD 1567A and whose manufacturers were willing to provide sufficient validation documentation. The following tasks illustrate the work completed during this study.

- **Task 1 - Identify Commercially Available Predetermined Time Systems**

  In order to identify currently available predetermined time systems, the project team performed the following subtasks:

  - Subtask 1.1 - Literature Survey
    During this subtask a computerized literature search was conducted by accessing an estimated 20 data bases. (See Exhibit 1.0.) As a result of this review, approximately 20 articles addressing MIL STD 1567A, predetermined time systems, and evaluation procedures were identified and retrieved.

  - Subtask 1.2 - Development of Forms
    Prior to soliciting system-related data from system vendors, an introductory letter and survey questionnaire were developed and sent to each prospective system manufacturer. (See Exhibit 2.0.) The questionnaire dealt with general system-related data and provided team members with a guide to use during follow-up phone surveys.

- Subtask 1.3 - Phone Contact Procedures

  Approximately three days after having sent the questionnaire to vendors, project team members initiated phone surveys. During those phone surveys, 16 vendors were interviewed and 30 predetermined time systems were identified for evaluation.

- **Task 2 - Market Survey Briefing**

  Having identified and surveyed vendors, a briefing was prepared and presented to Air Force personnel. During this meeting, the following data was presented:

  - Systems identified and general description data. (See Exhibit 3.0.)

  - Recommendations as to systems to be further evaluated. (See Exhibit 4.0.)

  - Procedures to be used in handling confidential and/or proprietary system data provided by vendors.

  - Approach to be used in evaluating and ranking systems.

- **Task 3 - Evaluate Systems Identified**

  Utilizing system data provided by the vendors, a MIL STD 1567A compliance evaluation for each system was completed. Based on this evaluation, additional data required was identified for collection during future tasks. Having completed the evaluation, a final compliance summary was prepared. (See table in System Descriptions Section.)

- **Task 4 - Evaluate System Validation Documentation**

  Utilizing the statistical data provided by the vendors, an evaluation was conducted as to the approach used and the validity of the backup data provided. The validation process included the use of the student's "t" test for matched-pair observations, validation of basic

element structures, and accumulated system accuracy. Based on this review, it became apparent that the following system validation was commonplace among the vendors:

- Statistical data analyzing the micromotions and/or basic detail was no longer available; or, if available, not able to be provided; or would involve extensive in-depth review of motion films and analyses.

- Basic system validation has been based on comparisons to other predetermined time systems, with the majority comparing themselves to MTM-1.

During the validation process, two vendor site trips were conducted, with the following vendors visited:

°° Serge A. Birn (MSD)
°° MTM Association (MTM)
°° H. B. Maynard (MOST®)
°° METCUT Research Associates (METCUT)
°° General Analysis, Inc. (CUE)
°° Management Research Frontiers, Inc. (MODAPTS™)
°° Methods Management (MANPRO™)
°° Management Science, Inc. (UNIVEL®)

- **Task 5 – <u>Prepare and Present Draft Report</u>**

Having concluded the data collection/validation effort, the project team utilized the data provided, prepared and presented the draft final report. This report included the following:

- Executive Summary
- Technical Approach
- System Accuracy
- System Descriptions

In addition to the draft report, validation data provided by the vendors was compiled and presented under separate cover.

- **Task 6 - Prepare Final Report**

  Incorporating review comments by Air Force representatives, a final report/reference guide was prepared including all comments, and submitted for final approval.

- **Task 7 - Prepare and Present Reference Guide**

  Utilizing the data provided by vendors, general system descriptions were prepared and sent to each vendor for their review and comments. Based on their comments, system descriptions were finalized and a draft Reference Guide was prepared and presented to the Air Force. In addition to the system descriptions, four additional sections were included in the draft Reference Guide as follows:

  - Preface
  - Work Measurement Overview
  - MIL STD 1567A Overview
  - System Accuracy

  Incorporating review comments by Air Force representatives, the final report and reference guide were combined into one report containing the following sections:

  - Preface
  - Executive Summary
  - Technical Approach
  - Work Measurement Overview
  - MIL STD 1567A Overview
  - System Descriptions
  - System Accuracy

WORK MEASUREMENT OVERVIEW

Man's desire to know how long it should take to perform a given task not only exists today, but has existed since ancient times. As might be expected, there can be numerous reasons for wanting to identify how long a particular task and/or job will take to complete. Although one reason may be no more than to satisfy our curiosity, realistically, work measurement is usually performed to provide management with an accurate and consistent basis in which to:

- Plan work
- Determine performance
- Cost products

As might be expected, management is continually faced with making decisions involving the efficient use of the company's resources, whether it be manpower, machines or material. Having available accurate times, management can more effectively plan and budget as well as direct the fabrication and assembly of parts and components into final product. Work measurement provides management a more complete and accurate tool to present how work is being performed. It is through this knowledge that management can make factual decisions and improvements to its respective manufacturing process.

Work measurement, therefore, is not only a means in which to establish times for tasks being performed, but a means to benefit management, the worker and ultimately the consumer.

The real value of analyzing work and developing engineered standards is to provide management with the ability to:

- Establish rational goals and objectives

- Measure/evaluate performance and utilization of resources (i.e., manpower, material and machines)

- Identify the true source of the problem

- Justify method/process changes

Although there are many techniques now available, the original concept used in developing standards was "guessing." Today's version of guessing, although no more accurate or faster, has become more sophisticated, is known as the "educated guess," and is supported by:

- Intuition
- Personal experience
- Inherent ability or inability to make a confident-sounding response

Once work is completed and recorded, data is available to be used in estimating future work standards. Based on this information, the second generation of standards development, "historical data," evolved. This approach accurately told what had taken place, but to be used to accurately predict what will happen in the future required two important assumptions:

- Manufacturing conditions, and the products which were the original basis for the standard, are the best and will not change.

- Tasks to be performed in the future will continue to be the same as those performed when the historical data was developed.

As increasing interest was placed on the development and accuracy of standards and measurement techniques, the third concept, "time study," evolved. Through the efforts of many early innovators of measurement techniques, work was viewed as something which could be controlled and/or engineered. Basically, there was no known reason why work should be performed in a haphazard manner, utilizing poor methods. Based on the assumption that workers could be instructed in the best method to perform specified tasks, it was concluded that each task should be broken down into basic elements which could then be arranged to produce a more efficient approach to performing the work. To accomplish this, a stopwatch was then used to determine actual times for each of these tasks. To be able to use these times, for other workers performing

the same or similar tasks, required the analyst to rate the individual's work pace/skill and adjust the time to meet a level reflecting 100% effort and skill. Although a widely used technique, time study had three significant drawbacks:

- The analyst must have the skill and experience to accurately rate or compare the operator to the 100% performance level.

- No matter how expensive and/or accurate the stopwatch may be, it cannot accurately forecast or predict times for future situations. Its basic capability is in developing times for what has already occurred.

- Considering the variety of tasks being performed, the number of observations required, and how well the method has been defined, time study can be a very labor-intensive and costly technique.

Using the time study approach of breaking tasks into basic elements, it became apparent that the majority of manual operations are combinations of basic elements. By studying each of these elements, early engineers were able to determine the most effective work methods, which resulted in reduced motion content for a given work task. This approach soon became known as motion study. By combining time study with motion study, the best of both techniques were realized and "predetermined time systems" (PTS) were created. Each of the PMTS developed utilizes time/motion-study data to assign times to individual basic motions. Utilizing these predetermined times and motions, the measurement process becomes simply a procedure of selecting the best method or motion sequence to perform a given task and assigning the appropriate pre-established time for each of the motions selected. This approach provides the engineer with the ability to:

- Predict future task time requirements.

- Utilize a stopwatch for minor process times.

- Eliminate the need to rate operator performance. (Most systems have leveled their times to reflect 100% performance.)

- Focus on the work performed and method used.

In addition to the above-mentioned advantages, a predetermined time system also provides a cost-effective approach to developing, implementing and maintaining work standards.

Over the past 10 years, computers have played an integral part in enhancing the flow of information. Realizing the benefits which can be derived from utilizing computers for data flow and analysis, it was only a matter of time before industrial engineers began using the computer to develop and maintain standards. Utilizing the computer's speed, accuracy, and ability to sort, the "computerized" phase of measurement techniques began to evolve. Having a computerized system available for developing and maintaining standards allows the analyst to focus on more productive tasks by:

- Eliminating routine work, the majority of paperwork and the use of a stopwatch.

- Allowing changes to shop floor conditions to be easily implemented and documented.

- Allowing standards to be automatically maintained and updated.

- Performing analyses two to five times faster than with manual predetermined systems.

Historically, the major reasons management has been reluctant to develop and implement engineered standards has been cost, a lack of awareness and understanding as to systems currently available, and which system best fits the company's needs. With the development of predetermined and computerized systems, the cost of implementing and maintaining a standards program has been reduced when compared to previously available techniques. Therefore, the major obstacle in the decision process is the selection of the most

appropriate system. In general, during the selection process, the following guidelines should be followed:

- High-level measurement systems should be practiced only by properly trained individuals. Systems should provide controlled and unified training.

- Since work measurement should be used as a management tool for identifying potential cost savings, it is essential that the systems selected be method-sensitive.

- Measurement systems used should provide a greater benefit than the cost of measuring the work; therefore, the system selected should be cost-effective in its application without affecting its accuracy.

- Measurement systems should provide a reliable way for management to realize the benefits of increased productivity; therefore, the system selected should provide an accurate data base in which management can make decisions as it relates to:

  - Scheduling
  - Product design
  - Methods improvement
  - Staffing requirements

In summary, the system best suited for a given manufacturing environment is the one that meets established goals and provides the required level of accuracy at a reasonable cost. It is evident that selecting an appropriate system requires a sufficient amount of review, analysis and coordination. When this effort has been ignored, the system selected often does not meet the above criteria, places an undue cost burden to maintain and update, creates inconsistencies in its data base, and provides management with inaccurate data.

It is the consensus of the authors of this final report and reference guide that it is the intent of MIL STD 1567A (see MIL STD 1567A Overview) to assist defense contractors in achieving increased discipline in their work measurement programs, resulting in improved productivity and efficiency. In addition, it is the objective of the Air Force to assist contractors in identifying and selecting appropriate measurement systems by providing a reference guide which presents, in summary fashion, currently available predetermined time systems.

MIL STD 1567A OVERVIEW

FOREWARD

The purpose of this standard is to assist in achieving increased discipline in contractors' work measurement programs with the objective of improved productivity and efficiency in contractor industrial operations. Experience has shown that excess manpower and lost time can be identified, reduced, and continued method improvement made regularly where work measurement programs have been implemented and conscientiously pursued.

Active support of the program by all affected levels of management, based on an appreciation of work measurement and its objectives is vitally important. Work measurement and the reporting of labor performance is not considered an end in itself but a means to more effective management. Understanding the implication inherent in the objectives of the work measurement program will promote realization of its full value. It is important that objectives be presented and clearly demonstrated to all personnel who will be closely associated with the program.

The following are benefits which can accrue as a result of the employment of a work measurement program:

(a) Achieving greater output from a given amount of resources.

(b) Obtaining lower unit cost at all levels of production because production is more efficient.

(c) Reducing the amount of waste in performing operations.

(d) Reducing extra operations and the extra equipment needed to perform these operations.

(e) Encouraging continued attention to methods and process analysis because of the necessity for achieving improved performance.

(f) Improving the budgeting process and providing a basis for price estimating, including the development of Government Cost Estimates and should cost analyses.

(g) Acting as a basis for planning for long-term manpower, equipment and capital requirements.

(h) Improving production control activities and delivery time estimation.

(i) Focusing continual attention on cost reduction and cost control.

(j) Helping in the solution of layout and materials handling problems by providing accurate figures for planning and utilization of such equipment.

(k) Providing an objective and measured base from which management and labor can project piecework requirements, earnings, and performance incentives.

While recognizing the benefits that may normally be expected from the requirement for a work measurement system, it is DOD policy to selectively apply and tailor standardization documents to to ensure their cost-effective use in the acquisition process. Each program office should carefully consider, within DOD and Service guidelines, benefits and costs of imposing MIL STD 1567 on each specific acquisition. Contractors may propose document application and tailoring modifications with supporting rationale for such modifications.

The DOD is committed to development and coordination with industry of detailed application guidance to accompany MIL STD 1567. The purpose of this guidance is to provide non-contractual information on when and how to use the document, the source of and flexibility inherent within specific document requirements, information on what is required to satisfy document requirements, and the extent of Government review and approval. The guidance is intended to promote consistency in application and interpretation of MIL STD 1567 requirements.

Until this guidance can be issued in the form of an "Application Guidance" appendix to MIL STD 1567, or in a separate Military Handbook, the following applies:

(a) Use and correct application of appropriate predetermined time systems can be assumed to satisfy Government requirements for system accuracy.

(b) The contractor and the Government are encouraged to come to an early agreement of what constitutes an acceptable system satisfying the intent of this standard.

(c) Care should be exercised in the use of a work measurement system to ensure that the overall intent is not lost. Management understanding and attention to the manufacturing process is necessary for increased productivity. Work measurement provides one of the tools; however, misuse could result in reduced work-force motivation and productivity.

Feedback on the success or difficulties encountered (benefits and costs) in the application of this standard on specific contracts is encouraged. Contractor/industry and Government experience should be forwarded to the following address: Commander, Air Force Systems Command, Attn: ALX, Command Standardization Office, Andrews AFB DC 20334.

1. Scope

1.1 Purpose. This standard requires the application of a disciplined work measurement program as a management tool to improve productivity on those contracts to which it is applied. It establishes criteria which must be met by the contractor's work measurement programs and provides guidance for implementation of these techniques and their use in assuring cost effective development and production of systems and equipment.

1.2 Applicability. This standard is applicable to new/follow-on contracts, including modifications, as shown in paragraphs 1.2a, 1.2b, 1.2c, 1.2.1 below. The dollar thresholds indicated are to be based on the current Five-Year Defense Program (FYDP) budget submissions.

a. Full-scale acquisition-program developments which exceed $100 million.

b. Production, which may include some types of depot-level maintenance repair or overhaul, that exceeds $20 million annually or $100 million cumulatively. It shall not be applied to contracts or subcontracts for construction, facilities, off-the-shelf commodities, time and materials, research, study, or developments which are not connected with an acquisition program.

c. This standard is not applicable to ship construction, ship system contracts which have low-volume non-repetitive production runs, or service-type contracts.

1.2.1 Subcontracting. When this standard is applied to prime development or production contracts, it shall also be applied to related subcontracts and/or modifications which exceed $5 million annually or $25 million cumulatively. If it is determined by the prime contractor that such application is not cost-effective or is inappropriate for other reasons, the prime contractor may request the Government to waive the specific application. Requests for waivers shall be supported with the data used to make the determination.

1.3 Contractual Intent. This standard requires the application of a documented work measurement system. This standard further requires that the contractor apply procedures to maintain and audit the work measurement system. It is not the intent of this standard to prescribe or imply organization structure, management methodology, or the details of implementation procedures.

1.4 Corrective Actions. When surveillance by the contractor or the Government discloses that the work measurement program does not meet the requirements of this standard, a plan shall be initiated to expeditiously assure that corrective measures shall be implemented, demonstrated and documented. The contractor's system is subject to disapproval by the Government whenever it does not meet the requirements of this standard.

1.5 Documentation. The work measurement program shall include sufficient documentation to assure effective operation of the program and to provide for internal audits as required by paragraph 5.14. Documentation shall specify organizational responsibilities, state policies, and provide operational procedures and instructions. The results of contractor system audits and plans for corrective actions shall be made readily available to the Government for review.

2. Reference Documents

Not Applicable

3. Definitions

3.1 Actual Hours. An amount determined on the basis of time incurred as distinguished from forecasted time. Includes standard time properly adjusted for applicable variance.

3.2 Earned Hours. The time in standard hours credited to a worker or group of workers as the result of successfully completing a given task or group of tasks; usually calculated by summing the products of applicable standard times multiplied by the completed work units.

3.3 Labor Efficiency. The ratio of earned hours to actual hours spent on the same increments of work during a reporting period. When earned hours equal actual hours, the efficiency equals 100%.

3.4 Methods Engineering. The analyses and design of work methods and systems, including technological selection of operations or processes, specification of equipment type, and location.

3.5 Operation Analysis. A study which encompasses all those procedures concerned with the design or improvement of production, the purpose of the operation or other operations, inspection requirements, materials used and the manner of handling material, setup, tool equipment, working conditions, and methods used.

3.6 Predetermined Time System. An organized body of information, procedures and techniques employed in the study and evaluation of manual work elements. The system is expressed in terms of the motions used, their general and specific nature, the conditions under which they occur, and their previously determined performance times.

3.7 Realization Factor.

(a) A ratio of total actual labor hours to the standard earned hours.

(b) A factor by which labor standards are multiplied when developing actual/projected man-hour requirements.

3.8 Subcontract. A contract between the prime contractor and a third party to produce parts, components, or assemblies in accordance with the prime contractor's designs, specifications or directions, and applicable only to the prime contract.

3.9 Touch Labor. Production labor which can be reasonably and consistently related directly to a unit of work being manufactured, processed or tested. It involves work affecting the composition, condition or production of a product; it may also be referred to as "hands-on labor" or "factory labor."

NOTE: As used in this standard, touch labor includes such functions as machining, welding, fabricating, setup, cleaning, painting, assembling, functional testing of production articles and that labor required to complete the manually-controlled process portions of the work cycle.

3.10 Touch Labor Standard. A standard time set on a touch labor operation.

3.11 Type I Engineered Labor Standards. These are standards established using a recognized technique such as time study, standard data, a recognized predetermined time system, or a combination thereof to derive at least 90% of the normal time associated with the labor effort covered by the standard and meeting specific requirements of paragraph 5.1. Work sampling may be used to supplement or as a check on other, more definitive techniques.

3.12 Type II Labor Standard. All labor standards not meeting the criteria established in paragraph 5.1.

3.13 Standard Time Data. A compilation of all elements that are used for performing a given class of work with normal elemental time values for each element. The data is used as a basis for determining time standards on work similar to that from which the data were determined.

3.14 Touch Labor Normal/Standard Time. Normal time is the time required by a qualified worker to perform a task at a normal pace to complete an element, cycle or operation, using a prescribed method. The personal, fatigue, and unavoidable delay allowance added to this normal time results in the standard time.

3.15 Operation. (1) A job or task consisting of one or more work elements, normally done essentially in one location; (2) the lowest-level grouping of elemental times at which PF&D allowances are applied.

3.16 Element. A subdivision of the operation composed of a sequence of one or several basic motions and/or machine or process activities, which is distinct, describable and measurable.

4. General Requirements

4.1 General. Minimum requirements which must be met in the implementation of an acceptable work measurement program are:

a. An explicit definition of standard time that shall apply throughout the jurisdiction of work measurement.

b. A work measurement plan and supporting procedures.

c. A clear designation of the organization and personnel responsible for the execution of the system.

d. A plan to establish and maintain engineered labor standards to known accuracy.

e. A plan to conduct methods engineering studies to improve operations and to upgrade Type II labor standards to Type I Engineered Labor Standards in accordance with requirements of paragraph 5.4.

f. A defined plan for the use of labor standards as an input to budgeting, estimating, production planning, and "touch labor" performance evaluation.

g. A plan to ensure that system data is corrected when labor standards are revised according to paragraph 5.11 below.

5. Specific Requirements

5.1 Type I Engineered Labor Standards. All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level. For short operations, the accuracy requirement may be better met by accumulating small operations into super operations whose times are approximately one-half hour. Type I standards must include:

a. Documentation of an operations analysis.

b. A record of standard practice or method followed when the standard was developed.

c. A record of rating or leveling.

d. A record of the standard time computation including allowances.

e. A record of observed or predetermined time system time values used in determining the final standard time.

5.1.1 Predetermined Time Systems. It is not the intent of this Military Standard to challenge the accuracy of those predetermined time systems whose inherent accuracy meets the requirements of paragraph 5.1. However, when a predetermined time system is used, it shall be incumbent on the contractor to demonstrate to the Government that the accuracy of the original data base has not been compromised in application or standards development.

5.2 Operations Analysis. Operations analysis is considered an integral part of the development of a Type I Engineered Labor Standard. An operations analysis shall be accomplished and recorded prior to the determination of a Type I standard and in the improvement of established labor standards.

5.3 Standard Data. The contractor shall take full advantage of available standard time data of known accuracy and traceability.

5.4 Labor Standards Coverage. The contractor shall develop and implement a Work Measurement Coverage Plan which provides a time-phased schedule for achieving 80% coverage of all categories of touch labor hours with Type I standards. (See 3.9, Touch Labor.)

5.4.1 Cost Trade-off Analysis. The Work Measurement Coverage Plan shall be based on cost trade-off analyses which consider the status and effectiveness of the contractor's existing work measurement program.

5.4.2 Initial Coverage. Type II Standards are acceptable for initial coverage. All Type II standards shall be approved by the oragnization(s) responsible for establishing and implementing work measurement standards and estimating when Type I Standards have not yet been developed.

5.4.3 Upgrading. The Work Measurement Touch Labor Coverage Plan shall provide a schedule for upgrading Type II to Type I Standards.

5.5 Leveling/Performance Rating. All time studies shall be rated by using recognized techniques.

5.6 Allowances. Allowances for personal, fatigue, and unavoidable delays shall be developed and included as part of the labor standard. Allowances should not be excessive or inconsistent with those normally allowed for like work and conditions.

5.7 Estimating. The contractor's procedures shall describe how touch labor standards are utilized to develop price proposals.

5.8 Use of Labor Standards. Labor standards shall be used:

5.8.1 Budgets, Plans, and Schedules. As an input to developing budgets, plans and schedules, when available.

5.8.2 Touch Labor Hours. As a basis for estimating touch labor hours when issuing changes to contracts and as a basis for estimating the prices of initial spares, replenishment spares and follow-on production buys, when available.

5.8.3 Measuring Performance. As a basis for measuring touch labor performance.

5.9 Realization Factor. When labor standards have been modified by realization factors, major elements which contribute to the total factor shall be identified. The analysis supporting each element shall be available to the Government for review.

5.10 Labor Efficiency. A forecast of anticipated touch labor efficiency shall be used in manpower planning, both on a long-range and current scheduling basis.

5.11 Revisions. Labor standards shall be reviewed for accuracy and appropriate system data revision shall be made when changes occur to:

a. Methods or procedures
b. Tools, jigs, and fixtures
c. Workplace and work layout
d. Specified materials
e. Work content of the job

5.12 Production Count. Work units shall be clearly and discretely defined so as to cause accurate measurement of the work completed and shall be expressed in terms of completed:

a. End items
b. Operations
c. Lots or batches of end items

5.12.1 Partial Credit. In those cases where partial production credit is appropriate, the work measurement procedures shall define the method to be used to permit a timely and current production measure.

5.13 Labor Performance Reporting. The contractor's work measurement program shall provide for periodic reporting of labor performance. The report shall be prepared at least weekly for each work center and shall be summarized at each appropriate management level; it shall indicate labor efficiency and shall compare current results with pre-established contractor goals.

5.13.1 Variance Analysis. Labor performance reports shall be reviewed by supervisory and staff support functions. When a significant departure from projected performance goals occurs, a formal written analysis which addresses causes and corrective actions shall be prepared.

5.13.2 Report Retention. Performance reports and related variance trend analyses shall be retained for a six-month period.

5.14 System Audit. The contractor shall use an internal review process to monitor the work measurement system. This process shall be so designed that weaknesses or failures of the system are identified and brought to the attention of management to enable timely corrective action. Written

procedures shall describe the audit techniques to be used in evaluating system compliance.

5.14.1 Scope of Audit. The audit shall cover compliance with the requirements of this standard at least annually. The audit, based upon a representative sample of all active labor standards and work measurement activities, shall determine:

a. The validity of the prescribed method and the accuracy of the labor standard time values as validated against the data baseline.

b. Percent of coverage by Type I and Type II labor standards.

c. Effectiveness of the use of labor standards for planning, estimating, budgeting and scheduling.

d. The timeliness, accuracy and traceability of production-count reporting.

e. The accuracy of labor performance reports.

f. The reasonableness and attainment of efficiency goals established.

g. The effectiveness of corrective actions resulting from variance analyses.

5.14.2 Audit Reports. A copy of the audit findings shall be retained in company files for at least a two-year period and shall be made available to the Government designated representative for review upon request.

SUMMARY

The charts on the following pages summarize each system evaluated and are divided into two sections. The first section relates to criteria outlined in Paragraph 5.1 of MIL STD 1567A while the second section relates to basic system criteria.

UNITED STATES AIR FORCE
MIL. STD. 1567A COMPLIANCE SUMMARY
PTS VENDOR REVIEW

CRITERIA	PREDETERMINED TIME SYSTEMS									
	UNIVEL (MICROCAM, UNIVATION)	MANPRO (COMPUTER)	MTM-1 (4M,2M)	MTM-2 (ADAM)	MTM-3	MTM-MEK (4M,2M,ADAM)	MTM-UAS (4M,2M,ADAM)	MTM-V (4M,2M,ADAM)	MTM-TE (4M,2M)	MTM-M (4M,2M)
MIL. STD. 1567A COMPLIANCE: (PER SECTION 5.1)										
1) SYSTEM THEORETICAL ACCURACY VERIFIED.	•	•	•	•	•	•	•	•	•	•
2) PROVIDES AUDIT TRAIL/DETAILED DOCUMENTATION:										
- DOCUMENTATION OF ANALYSIS	•	•	•	•	•	•	•	•	•	•
- RECORD OF METHOD USED WHEN STANDARD WAS DEVELOPED	•	•	•	•	•	•	•	•	•	•
- RECORD OF RATING OR LEVELING	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
- RECORD OF STANDARD TIME COMPUTATION INCLUDING ALLOWANCES	•	•	•	•	•	•	•	•	•	•
- RECORD OF PTS TIME VALUES USED IN DETERMINING STANDARD TIME	•	•	•	•	•	•	•	•	•	•
BASIC SYSTEM CRITERIA:										
1) SYSTEM BACK-UP DATA AND/OR COMPARISONS TO OTHER PTMS AVAILABLE	•	•	•	•	•	•	•	•	•	•
2) SYSTEM APPLICATION METHOD:										
-MANUAL			•	•	•	•	•	•	•	•
-PC	•	•	•	•		•	•	•	•	•
-MICRO	•	•	•	•		•	•	•	•	•
-MAINFRAME/MINI	•		•	•		•	•	•	•	•
3) SYSTEM FLEXIBILITY:										
-REPETITIVE CYCLES	•	•	•	•			•		•	•
-NON-REPETITIVE CYCLES	•	•			•	•		•		
-SHORT CYCLE	•	•	•	•	•		•		•	•
-LONG CYCLE	•	•			•	•		•	•	
-NOT APPLICABLE										
4) TRAINING/CERTIFICATION REQUIRED:										
-SELF-TAUGHT	•		•		•			•		
-SEMINAR	•	•	•	•	•	•	•	•	•	•
-CERTIFICATION EXAM	•		•	•	•	•	•	•	•	•
5) SYSTEM MAINTENANCE/SUPPORT:										
-PROVIDE UPDATES	•	•	•	•	•	•	•	•	•	•
-RE-CERTIFICATION			•	•	•	•	•	•	•	•
-TECHNICAL ASSISTANCE	•	•	•	•	•	•	•	•	•	•

• INDICATES VENDORS MET COMPLIANCE AND/OR CRITERIA

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CRITERIA	PREDETERMINED TIME SYSTEMS									
	MTS (CASA I, II)	G.E. STND DATA (CASA III)	CUE (DART)	MSD (MOD II)	NAVAIR ESD (COMPUTER)	MODAPTS PLUS (MODAPTS PLUS-SUITE)	BASIC MOST (COMPUTER)	MINI MOST (COMPUTER)	MAXI MOST (COMPUTER)	WORK-FACTOR (WOCOM II)
MIL. STD. 1 A COMPLIANCE: (PER SECTION 5.1)										
1) SYSTEM THEORETICAL ACCURACY VERIFIED.	•		•	•		•	•	•	•	•
2) PROVIDES AUDIT TRAIL/DETAILED DOCUMENTATION:										
• DOCUMENTATION OF ANALYSIS	•	•	•	•	•	•	•	•	•	•
• RECORD OF METHOD USED WHEN STANDARD WAS DEVELOPED	•	•	•	•	•	•	•	•	•	•
• RECORD OF RATING OR LEVELING	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
• RECORD OF STANDARD TIME COMPUTATION INCLUDING ALLOWANCES	•	•	•	•	•	•	•	•	•	•
• RECORD OF PTS TIME VALUES USED IN DETERMINING STANDARD TIME	•	•	•	•	•	•	•	•	•	•
BASIC SYSTEM CRITERIA:										
1) SYSTEM BACK-UP DATA AND/OR COMPARISONS TO OTHER PTMS AVAILABLE	•		•	•		•	•	•	•	•
2) SYSTEM APPLICATION METHOD:										
-MANUAL	•	•	•	•	•	•	•	•	•	•
-PC	•		•	•		•	•	•	•	•
-MICRO	•	•	•	•		•	•	•	•	•
-MAINFRAME/MINI	•	•			•		•	•	•	
3) SYSTEM FLEXIBILITY:										
-REPETITIVE CYCLES	•		•	•	•	•		•		•
-NON-REPETITIVE CYCLES		•	•	•	•	•	•		•	•
-SHORT CYCLE	•		•	•	•	•		•		•
-LONG CYCLE		•	•	•	•	•	•		•	•
-NOT APPLICABLE										
4) TRAINING/CERTIFICATION REQUIRED:										
-SELF-TAUGHT				•		•	•	•	•	
-SEMINAR	•	•	•	•	•	•	•	•	•	•
-CERTIFICATION EXAM			•	•		•	•	•	•	•
5) SYSTEM MAINTENANCE/SUPPORT:										
-PROVIDE UPDATES	•	•	•	•		•	•	•	•	•
-RE-CERTIFICATION				•	•		•	•	•	
-TECHNICAL ASSISTANCE	•	•	•	•	•	•	•	•	•	•

• INDICATES VENDORS MET COMPLIANCE AND/OR CRITERIA

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CRITERIA	MACHINING OPERATIONS DATA	
	AM COST ESTIMATOR	METCUT (CUTDATA)
MIL. STD. 1567A COMPLIANCE: (PER SECTION 5.1)		
1) SYSTEM THEORETICAL ACCURACY VERIFIED.	•	
2) PROVIDES AUDIT TRAIL/DETAILED DOCUMENTATION:		
- DOCUMENTATION OF ANALYSIS	•	•
- RECORD OF METHOD USED WHEN STANDARD WAS DEVELOPED	•	•
- RECORD OF RATING OR LEVELING	N/A	N/A
- RECORD OF STANDARD TIME COMPUTATION INCLUDING ALLOWANCES	•	•
- RECORD OF PTS TIME VALUES USED IN DETERMINING STANDARD TIME	•	•
BASIC SYSTEM CRITERIA:		
1) SYSTEM BACK-UP DATA AND/OR COMPARISONS TO OTHER PTMS AVAILABLE	•	
2) SYSTEM APPLICATION METHOD:		
-MANUAL	•	•
-PC	•	•
-MICRO	•	•
-MAINFRAME/MINI		•
3) SYSTEM FLEXIBILITY:		
-MACHINING PROC. ONLY		•
-MACHINING PROC. AND MANUAL OPNS.	•	
-REPETITIVE CYCLES	•	•
-NON-REPETITIVE CYCLES	•	•
-SHORT CYCLE	•	•
-LONG CYCLE	•	•
-NOT APPLICABLE		
4) TRAINING/CERTIFICATION REQUIRED:		
-SELF-TAUGHT	•	•
-SEMINAR	•	
-CERTIFICATION EXAM		
5) SYSTEM MAINTENANCE/SUPPORT:		
-PROVIDE UPDATES	•	•
-RE-CERTIFICATION		
-TECHNICAL ASSISTANCE	•	•

• INDICATES VENDORS MET COMPLIANCE AND/OR CRITERIA

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MIL. STD. 1567A COMPLIANCE SUMMARY
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CRITERIA	SOFTWARE PACKAGES		
	EASE (MTM-2)	CSD (4M)	SUPERCAPES (ANY) (1)
MIL. STD. 1567A COMPLIANCE: (PER SECTION 5.1)			
1) SYSTEM THEORETICAL ACCURACY VERIFIED.	N/A	N/A	N/A
2) PROVIDES AUDIT TRAIL/DETAILED DOCUMENTATION:			
- DOCUMENTATION OF ANALYSIS	•	•	•
- RECORD OF METHOD USED WHEN STANDARD WAS DEVELOPED	•	•	•
- RECORD OF RATING OR LEVELING	N/A	N/A	N/A
- RECORD OF STANDARD TIME COMPUTATION INCLUDING ALLOWANCES	•	•	•
- RECORD OF PTS TIME VALUES USED IN DETERMINING STANDARD TIME	•	•	•
BASIC SYSTEM CRITERIA:			
1) SYSTEM BACK-UP DATA AND/OR COMPARISONS TO OTHER PTMS AVAILABLE	N/A	N/A	N/A
2) SYSTEM APPLICATION METHOD:			
-PC	•	•	•
-MICRO	•	•	•
-MAINFRAME/MINI		•	•
3) SYSTEM FLEXIBILITY:			
-REPETITIVE CYCLES			
-NON-REPETITIVE CYCLES			
-SHORT CYCLE			
-LONG CYCLE			
-NOT APPLICABLE	N/A	N/A	N/A
4) TRAINING/CERTIFICATION REQUIRED:			
-SELF-TAUGHT	•	•	
-SEMINAR	•	•	•
-CERTIFICATION EXAM	•	•	•
5) SYSTEM MAINTENANCE/SUPPORT:			
-PROVIDE UPDATES	•	•	•
-RE-CERTIFICATION			
-TECHNICAL ASSISTANCE	•	•	•

(1) DOES PROVIDE OWN STANDARD DATA PROGRAM
• INDICATES VENDORS MET COMPLIANCE AND/OR CRITERIA

MOTION TIME SURVEY (MTS)

CONTACT: Gary R. Conte or Daniel T. Keonig
COMPANY: General Electric Company, Corp. Engineering & Manf.
ADDRESS: 1285 Boston Avenue, Bridgeport, CT 06601-2385
PHONE: (203) 382-2719

SYSTEM HISTORY:

The first attempts to utilize motion study at General Electric were initiated in 1933-34 with Segur's System, Motion Time Analysis, which applied time values to movements. Enhancements to this technique were made by adjusting Segur's times to values which could be maintained by an operator over a full day. This was done by developing a method which compensated for reduction in operation time as an operator gained proficiency. In addition, the manual and the method of recording were abbreviated. This revised version was known as Modified Motion-Time Analysis. In 1948 a committee was formed to evaluate the various motion time data systems and **Motion Time Survey (MTS)** was adopted for use throughout the General Electric Company.

The first computerized version of MTS, **Computer Aided Station Analysis I (CASA I)** was developed by General Electric and was first installed in December 1982. As a result of continuous systems development and enhancements, General Electric upgraded the CASA I software package into a software package that could be used by plants with medium- to high- volume needs and was compatible with a larger number of computer hardware systems. **Computer Aided Station Analysis II (CASA II)** was introduced in early 1985 and was first installed in March 1985.

SYSTEM DESCRIPTION:

Motion Time Survey (MTS) is a manual, predetermined time system in which the basic movements and motions required to perform most industrial operations have been combined into five groups designated by Transports, Gets, Places, Precision, and Miscellaneous. Time values have been developed to represent the total time required to perform each movement within a group.

Computer Aided Station Analysis I and II are computer software packages that use the **MTS** Data base. Each of these systems have features which make development and maintenance of work standards easier by requiring less time than the manual approach. System features are as follows:

CASA I:

- Compiled Programs - Faster Response
- Improved Functional Operation Capabilities
- Enhanced Workplace Layout Graphics
- Universal Data Retrieval Capability
- Compatible with IBM XT or AT
- Hard-disk Data Storage Option

CASA II:

- Multi-terminal Network - Hard-disk Data Storage
- "Oracle" Relational Data-base Management System
- Enhanced Analysis Capabilities - Fast response
- Universal Data (Plant Data) Generation and Insertion
- Operational Standard Generation
- Mass Updating of Universal Data Changes
- Potential to Interface and Support "CAPP" (Computer-Aided Process Planning) Systems

SYSTEM APPLICATION:

MTS can be applied either manually or by computer as follows:

- **MANUAL:**

  The MTS system utilizes a standard form, the Motion Time Survey Worksheet, for documenting the methods used to perform work and their appropriate time values.

  Initially the analyst must document the workplace layout where the work is performed. This includes arrangement of tools, materials, and equipment.

  The actual analysis of the operation is documented on the MTS worksheet. MTS is based upon the principle that, in its simplest form, any operation

becomes a series of related get-and-place elements. The entire operation is recorded, listing consecutive elements of work performed by the operator's left hand and right hand. If visualized, the method must be verified by actual shop floor observation.

Time values documented on the worksheet are for one hand only as identified during the analysis of left-hand/right-hand performance. The longer required time becomes the recorded time. In recording the time values for each element, the transport is determined first, followed by the get or the place, the precision, and finally by any applicable miscellaneous item.

After the total time for each element has been calculated for the operation, allowances reflecting experience levels, and other applicable constraints, are determined and applied in order to arrive at the work standard for the studied activity.

MTS is best suited for **short-cycle** jobs that are **highly repetitive** with **no variations.**

- **COMPUTER:**

The methodology of the CASA I and CASA II systems are the same as MTS, although the application is different. The same information documented on the Motion Time Survey worksheet is input via computer into the CASA I, II systems. This is accomplished by using system-defined action codes. These action codes are in the form of working tables and tell the computer what additional inputs to expect and are set up to automatically ask for the required information. The action codes indicate different combinations of movement that are taking place (i.e., GET & PLACE, GET, GET & DISPOSE, etc.).

As with MTS, the computerized CASA I and II versions are best suited for **short-cycle, highly repetitive, no method-variation** activities.

The hardware systems on which the CASA I and CASA II software can operate are as follows:

- CASA I - IBM PC/XT or compatible computer (Single-user)
- CASA II - DEC/VAX, IBM/VM-CMS, Prime, Honeywell/DPS6 (Multi-user)

TRAINING/TECHNICAL ASSISTANCE:

The system vendor provides user training and implementation assistance in-house or at the user's facility. The training approach taken is a combination of classroom lecture and hands-on system application. MTS requires two weeks of training, and the CASA I and II systems require two to three weeks of training and implementation assistance. Additionally, a one-week instructor workshop is provided to train qualified individuals in the instruction of MTS and CASA I, II. No certification is required for use of the systems.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
Perpetual License Fee for MTS	$10,000
MTS Training (two weeks on-site)	$10,500
CASA I Software and Training (two weeks on-site)	$20,500
CASA II Software, Installation and Training(1) (three weeks on-site)	$57,500

NOTE: (1) Software requires Oracle Relational Data-base Management System (RDBMS) and FRIL interface language rights. The estimated costs for each are:

- FRIL Interface Language
  - Run-time version $10,000
  - Full-time version $50,000
- Oracle RDBMS $50,000 - $75,000

COMPLIANCE WITH MIL STD 1567A:

The MTS predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.
- A record of observed or predetermined time system time values used in determining the final standard time.
- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MTS predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- Easy to apply.

- Computerized application provides improved speed, accuracy and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" method-improvement scenarios.

- Generates good documentation of the work sequence or process being analyzed.

- System is well-accepted by direct labor personnel.

- The computer application can allow for direct input of operation descriptions, based on observation of the operation, without having to document the operations and then input into the system.

- Two computerized versions are available, each having its own capabilities and features, thus providing a user the ability to evaluate each based upon his particular needs.

- The system was developed by utilizing the system vendor's accepted terminology and may require interpretation by users outside of the company.

- The system is best suited for short-cycle, highly repetitive, no method-variation activities.

SYSTEM USERS:

General Electric has not actively marketed its systems outside of its company; however, those companies which were previously held by GE retained and are applying MTS, CASA I and CASA II. Specific areas in which the systems are currently being used, and the number of users in each area, are as follows:

- Electronics Assembly - 10
- Electrical/Mechanical - 32
- Consumer - 32
- Materials - 4
- External - 3

REFERENCE SOURCE:

General Electric Company

G.E. STANDARD DATA

CONTACT: Gary R. Conte and Daniel T. Koenig
COMPANY: General Electric Company, Corp. Engineering & Manufacturing
ADDRESS: 1285 Boston Avenue, Bridgeport, CT 06601
PHONE: (203) 382-2719

SYSTEM HISTORY:

G.E. Standard Data was developed by General Electric at the company's facility in Schenectady, New York, in 1963. The system's first application was in the same facility in 1965.

Computer Aided Station Analysis III (CASA III) was developed by General Electric in 1985. The system's first application was in June of 1985 at G. E.'s Space Systems, in Valley Forge, Pennsylvania.

The **Computer Aided Methods Analysis (CASA/CAMA)** integrated system is the latest development in support of General Electric's desire to integrate management's manufacturing decision-making activities.

SYSTEM DESCRIPTION:

G.E. Standard Data is a manual predetermined time system which is based on Motion Time Survey (MTS) analyses of:

- Body Movements
  - clean
  - file
  - equipment preparation
  - maintenance
- Hand Manipulations
- Layout and Mark
- Mental Progress
- Position and Align
- Secure and Loosen
- Tool Handling
- Measure and Gage

Time studies were used to determine times for using cranes, journal jacks, etc. G.E. Standard Data is comprised of 90 Standard Data Codes.

The Motion Time Survey elements used to develop the G.E. Standard Data are available in the manual, "Element Analysis for G.E. Standard Data", in which backup for all the standard data is provided.

CASA III is a computer software package that uses the G.E. Standard Data Base. CASA III was developed as an enhancement to the CASA II system and retains the prime features. The system utilizes the "ORACLE" Relational Data Base Management System and provides for four Variable Data Inputs, including use of G.E. Standard Data Tables, Plant Level Generated Tables and Formulas. CASA III also generates Universal and Operational Level Standards with mass updating capability. The CASA III system was developed to meet the needs of a large plant with low volume production.

CASA/CAMA is an integrated engineered time standards and process planning system using relational data base computer software. It is a mechanism for integrating engineered time standards and process planning into one computer-generated system. It provides for the integration of methods description, application of incremental standards, and the resulting generation of a process plan. CAMA can be fully integrated with the CASA II and CASA III systems and provide source data for Computer Integrated Manufacturing (CIM).

SYSTEM APPLICATION:

- **G.E. Standard Data**

  Uses a technique called "Coded Variables Technique" in the application of the system. This technique was developed to reduce the amount of time required to build application tables using standard data. The features of this technique are: 1) selection of elements of a standard is made from a small code book; 2) the necessary information to specify the elements of a standard are recorded in a definite pattern on an analysis form; 3) analysis form is designed so that associated connecting links (such as miscellaneous body moves, transports, and walking standards) can be recorded on the same line with the standard used to record the main activity; and 4) the lookup and extending of time values may be done by a clerk thus allowing the analyst to devote more time and effort to job analysis.

When using the coded variables technique for analyzing manual operations, the analysis is recorded on a preprinted analysis sheet. The analyst indicates on this sheet each standard that is used and the variables that determine the time to be allowed. After the analysis has been completed, the time values must be looked up in the coded variables tables and recorded on the analysis sheet. If the analysis was performed using the visualization process, it must be verified by actual shop floor observation. G.E. Standard Data is best suited for **long cycle, low repetition types of work.**

- **Casa III System**

In developing standards with the CASA III computer system, the analyst must perform the same job analysis activities as described for the manual application of G.E. Standard Data. The standards are developed on the computer screen by first inputting the "Header Information" which includes a standard number, definitions of move distances or transports for the work place, and description and location of objects in the work place. Next the elemental data relating to the activity is input by entering the appropriate action codes and variables. The CASA III system will automatically translate the codes and variables into verbage describing the activity. This verbage can be edited to give a more detailed activity description without altering the underlying action codes or variables. Each element of the standard development is entered in this manner until the entire activity has been input. The CASA III system automatically calculates the elemental time values and totals them for the standard. Any additional information needed to complete the standard, such as setup times, machine run times, allowances, prorates, etc., may be input.

The work environment best suited for using CASA III is **long cycle, low repetition types of work.** Typical operations that may be analyzed by any of the CASA systems are:

- Conveyor Assemblies
- Machine Tapping
- Drill Press
- Milling Machine
- Spot Welding
- Punch Press
- Hand Taping Operations
- Manual Portions of Automatic Machine Cycles
- Bench Assemblies
- Riveting Machines

The multiuser hardware systems on which the CASA III software can operate are as follows:

- DEC/VAX
- IBM/VM
- CMS
- PRIME
- HONEYWELL/DPS6

TRAINING/TECHNICAL ASSISTANCE:

The system vendor provides user training and implementation assistance in-house or at the user's facility. The training approach taken is a combination of classroom lecture and hands-on system application. G.E. Standard Data requires 80-120 hours of training, and the CASA III system requires approximately three weeks of training and implementation assistance. The CASA III/CAMA system requires approximately five weeks of on-site training and implementation assistance. Additionally, a one-week instructor workshop is provided to train qualified individuals in the instruction of G.E. Standard Data and the CASA III systems. No certification is required for use of the systems.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
° Perpetual License Fee for G.E. Standard Data.	$10,000
° G.E. Standard Data Training (2-3 weeks on-site)	$15,750
° CASA III Software, Installation and Training (3 weeks on-site) (1)	$67,500
° CASA III/CAMA Software, Installation, and Training (5 weeks on-site) (1)	$88,000

See "NOTE" on the following page.

NOTE: (1) Software requires Oracle Relational Data Base Management System (RDBMS), and FRIL Interface Language Rights. The estimated costs for each are:

- Oracle RDBMS - $50,000 - $75,000
- FRIL Interface Language:
  - Run-time version - $10,000
  - Full-time version - $50,000

COMPLIANCE WITH MIL STD 1567A:

The G.E. Standard Data system utilizes the time elements developed by the GE-MTS predetermined time system. The accuracy level of this system is directly related to the potential accumulated percent error which could not be determined, as the necessary statistical data could not be provided. Those basic requirements, as specified in the MIL STD, which are in question, are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.

Those requirements which the system **does** meet are as follows:

- Documentation of an operations analysis.

- A record of standard practice or method followed when the standard was developed.

- A record of rating or leveling.

- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the G.E. Standard Data predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- As a standard data system, it provides a substantial amount of standard data related primarily to mechanical and electronic manufacture, and assembly activities which reduces standards development efforts.

- Computerized application provides improved speed, accuracy and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" method improvement scenarios.

- The computerized system is fully integrated into a computer-aided process planning system (CAPPS) that is developed and supported by the system vendor.

- Generates good documentation of the work sequence or process being analyzed.

- The system was developed utilizing the system vendor's accepted terminology and may require interpretation by users outside of the company.

- The system is best suited for long cycle, low repetition types of work.

- The computer system user manual is somewhat brief due to the ongoing development of the system.

SYSTEM USERS:

General Electric has not actively marketed their systems outside of their company; however, those companies which were previously held by G.E. retained and are applying G.E. Standard Data and CASA III. Specific areas in which the systems are currently being used and the number of users in each area are as follows:

- Electronics Assembly - 5
- Electrical/Measurement - 11
- Consumer - 2

REFERENCE SOURCE:

General Electric Company

MTM-1, 4M, 2M

CONTACT: Dirk Rauglas, Dir.-Research & Tech. Sup.
COMPANY: MTM Association
ADDRESS: 1411 Peterson Avenue, Park Ridge, IL 60068
PHONE: (312) 823-7120

SYSTEM HISTORY:

The **Methods Time Measurement (MTM)** predetermined time system was developed from 1940 to 1948 by Harold B. Maynard, A. J. Stegemerten, and John L. Schwab. During that time, they were retained by Westinghouse Electric Corporation to implement a methods improvement program.

Films of operators performing common industrial operations were analyzed and broken down into the simplest of motions. Once isolated, each motion was rated and timed to arrive at an average time to perform the operational element. Further tests showed that the times developed for the operational elements could be applied to other jobs with consistent results. These studies became the basis for the first MTM tables.

The ensuing years consisted of continued development and validation. Cornell University conducted an independent investigation of the data and reported to the American Society of Mechanical Engineers that their investigation supported the methodology and approach used by MTM, and validated the accuracy of the data developed.

Since the system's inception, the MTM Association worldwide has continued research and development into facilitating the application of MTM-1 in those areas where application variations could affect the accuracy of standards developed from MTM-1 data. As a result, permutations of MTM-1 have evolved and shall be discussed individually within this reference guide.

SYSTEM DESCRIPTION:

MTM-1, the basis of the MTM family of predetermined time systems, uses a procedure which analyzes manual operations and/or methods into basic motions and assigns to each motion a time standard which is determined by the nature of the motion and the conditions under which it is made.

The MTM-1 system consists of seven action categories containing 26 basic motions, that are used to describe manual activities as follows:

ACTION CATEGORY	BASIC MOTION	BASIC CODE
Obtain Action	Reach	R
	Grasp	G
	Release	RL
Locate Action	Move	M
	Position	P
Rotate Action	Turn	T
	Crank	C
Force Action	Apply Pressure	AP
Recoil Action	Disengage	D
Eye Action	Eye Focus	EF
	Eye Travel	ET
Body Action	Foot Motion	FM
	Leg Motion	LM
	Sidestep	SS
	Turn Body	TB
	Walk	W
	Bend	B
	Arise Bend	AB
	Stoop	S
	Arise Stoop	AS
	Kneel One Knee	KOK
	Kneel Both Knees	KBK
	Arise Kneel One Knee	AKOK
	Arise Kneel Both Knees	AKBK
	Sit	SIT
	Stand	STD

SYSTEM APPLICATION:

MTM-1 can be applied manually or by using the computer system, 4M. Both applications are described on the following page:

- **MANUAL**:

The methodology used in applying the manual MTM-1 system to develop elemental, standard, and/or multilevel data is as follows:

- Observe and document the operation being performed. If visualized, the method must be verified by actual shop floor observation.

- Secure complete and detailed information about the operation, including the detailed identification of the operation, tools, work-place layout, and conditions.

- Analyze the operation to identify and classify all left/right hand motions or motion sequences required for performing the operation, and identify simultaneous motions. In the case of simultaneous motions, the greater time of the two is used.

- Record the motions using the proper MTM conventions for the system being used and document them on the MTM Activity Analysis Forms.

- Assign Time Values (TMUs) to the motions by entering the proper times from the MTM Data Card.

- Add up the time values to obtain the total time required for the operation studied. The time obtained will be the time required for an operator of average skill, working with average effort.

- Add the required allowances such as personal, fatigue, unavoidable delay, etc.

- Validate and apply the standard.

An example of an operation analysis using the manual MTM-1 system is shown on the following page.

MTM ASSOCIATION FOR STANDARDS AND RESEARCH
9-10 Saddle River Road
Fair Lawn, N.J. 07410

OPERATION: Tighten nut with open end wrench

Sheet ____ of ____
SYSTEM: MTM-
STUDY NO. ____
DATE: ____
ANALYST: ____

LEFT HAND DESCRIPTION	F	LH MOTION	TMU	RH MOTION	F	RIGHT HAND DESCRIPTION
Reach for open end wrench		R10B	11.5			
Grasp wrench		G1A	2.0			
Regrasp for control		G2	5.6			
Move wrench to other hand		M10A	11.3	R10A		Reach to wrench in other hand
		G3	5.6	G3		Transfer wrench from L.H. to R.H.
			20.4	M18C		Move wrench to nut
			9.1	P1SSE		Position wrench to nut
			2.5	M1A		Move wrench to nut
			8.9	M6B		Move wrench to tighten nut
			16.2	APB		Final tighten
			12.2	M10B		Move wrench aside to work bench
			2.0	RL1		Release wrench on work bench
			107.3			

- **COMPUTER**:

The **4M** system is a computer-based approach for creating and maintaining labor standards and standard data. The 4M Data generator provides MTM-1 precision through 4M Get/Place coding, automatic application of simo rules, and editing for error detection. The system generates standard reports, operator instructions, and MTM-1 backup of 4M elements. Features included with 4M are:

  - **Methods Improvement Indices:** a guide to work simplification and methods improvement.

  - **Data Base Maintenance:** allows the analyst to remove, add or modify data as required. A Mass Update routine utilizes a single command to update all standards effected by a given element change.

  - **Data Base Review:** allows the analyst to view the entire data base or any portion of the data base.

  - **Multilevel Data:** is supported for higher data levels.

  - **User-Defined Elements:** existing elements are loaded to the 4M system which handles these elements as it would any MTM-based element.

  - **Error Detection:** edit routines check all data prior to updating the data base. Error messages are automatically generated.

  - **Quick Change:** provides the engineer with the ability to create a new standard by referring to a similar operation currently on file.

  - **Internal Time Calculations:** identifies manual elements as being internal to a process element.

  - **Simulation Capability:** permits the analyst to test several methods before selecting the one to be used.

- **Operator Instructions:** provides detailed operator instructions in plain language for use by operating personnel.

- **Report Generation:** generates a series of reports designed to be utilized at all levels of the organization. These include:

  - 4M Element Analysis
  - 4M Operation Analysis
  - 4M Operation Analysis - Abbreviated
  - Operation Standard Report
  - Summary Operator Instructions
  - Operator Instruction Report
  - Element Master File Report
  - Operation Master File Report
  - Study Index File Report
  - Element Where-used Report
  - MTM Analysis

- **Formula Application:** provides formula capability which allows the user to develop, evaluate, and apply mathematical formulas.

An example which illustrates the 4M system is as follows:

- OBTAIN REQUIRED TOOLS FOR WIRING MOTOR

	LH MOTIONS					RH OR BODY MOTIONS	FREQ	PROCESS TIME	LH	RH	NET MANUAL
010	TOOLS WERE ALREADY ON BENCH WITH EXCEPTION OF PLIERS										
020				WPO -4	WALK OBS	TO CABINET FOR KEY				680	680
030				G12 -15	GET	KEY FROM HOOK				180	180
040				WPO -9	WALK OBS	TO CABINET FOR PLIERS				1530	1530
050				P221-8		INSERT KEY TO LOCK				314	314
060				T1S	TURN	KEY				28	28
070				G12 -6	GET	DRAWER				115	115
080	GET	KEY	G12 -5	PO2 -8		PULL DRAWER OPEN			108	106	108
090		SET KEY ON CABINET	P02 -8	G41 -6	GET	PLIERS			106	184	189
100				WPO -7	WALK OBS	BACK TO WORKSTATION				1190	1190
110				P02-13		PLACE PLIERS ON BENCH				1190	1190
						ELEMENT SUBTOTAL					4474

The 4M system is available in two versions as follows:

- **MOD IIA**: is an on-line interactive system which allows for establishment of standards through a terminal which can be is used for input, maintenance and inquiry. All error checks, warning displays, and corrections occur on an interactive real-time basis. The final job instruction sheets, standard documentation, and other reports may be requested and displayed through the terminal and transferred to a line printer for hard copy.

- **MOD IIB**: is a batch-processed system. The analyst develops the method on input sheets which are processed into card images and are run under the control of a Job Control Language (JCL). Various printed output reports are generated as requested. In addition, selected hardware configurations support the use of a Remote Job Entry (RJE) system for the input of data. Under this system the analyst utilizes a terminal for input, maintenance and inquiry of data. All error checks, warning displays, and corrections occur on an interactive basis, while all processing of data occurs on a batch basis.

The system vendor states that, based on discussions with MTM-1 instructors and practitioners and various tests, the speed of manually applying the MTM-1 system is conservatively estimated at 250 times the length of the cycle studied for an operation which is non-repetitive and requires the documentation of the operation. At its basic level the 4M computerized system is said to result in application speeds which are five to 10 times faster than the manual application speeds.

MTM-1 can be applied to manual activities which are definable in terms of the activity's content and beginning and completion points. The system vendor states that MTM-1 is best applied to **short-cycle jobs** that are **highly repetitive**, with **minimal method variations.**

The MTM-1 predetermined time system can be applied by computer using a number of software packages that have been developed utilizing the MTM-1 data. The MTM Association supports two computer-based systems which use MTM-1 data, 4M and 2M. The hardware configurations on which each system will operate are as follows:

<u>4M - MOD IIA</u>

- Data General
- DEC VAX 11/780
- IBM - IMS
- IBM - CICS
- IBM - PCXT, AT or compatible
- PRIME

<u>4M - MOD IIB</u>

- UNIVAC - 1100, 90/30
- IBM - OS, DOS
- IBM System 34, 36
- IBM System 38
- Hewlett Packard 3000

<u>2M</u>

- Is available on any of the hardware configurations listed above.

TRAINING/TECHNICAL ASSISTANCE:

Both lecture and programmed instruction formats are available for MTM-1 and 4M learning. 4M is a proprietary system and is only available through the MTM Association. MTM-1 training is available from four sources:

- MTM-licensed instructors as follows:
  - MTM Association
  - Self-employed
  - Consulting firms
  - Private or public-sector companies

The MTM Association determines analyst and instructor training requirements, maintains certification, and conducts periodic update examinations to assure analyst and instructor competence.

Two MTM-1 training courses are available:

- **MTM - 1A:** An 80-hour (two-week) course which includes complete coverage of the theory and principles of MTM-1, laboratory problems, and thorough practice in the analysis of industrial and business operations. **Blue Card™** certification in MTM-1 (80) is issued following successful completion of a written certification examination.

- **MTM - 1B:** A 40-hour optional course which upgrades MTM-1 certification to an MTM-1 (120) Blue Card™. It gives an appreciation of the MTM family systems. Other subjects include Methods Improvements with MTM, System Selection Parameters, Standard Data System Construction, and Occupational Economics. Blue Card™ certification in MTM-1 (80) for at least 60 days is a prerequisite for this course. Submission of evidence of MTM-1 application is required. The course is a prerequisite for MTM instructor candidates.

Blue Card™ certification is only issued following completion of MTM-Association-approved training courses. Applicators and instructors are recertified on a three-year cycle. The MTM Association prescribes procedures for reinstatement of lapsed certification.

SYSTEM COSTS:

The costs associated with the basic MTM-1, 4M - MOD II, and 2M systems are shown in the table on the following page:

COST CATEGORY	LIST PRICE	
	MTM ASSOC. MEMBERS	NON-MEMBERS
Public Training Courses from the MTM Association		
° MTM - 1A:	700	$ 800
° MTM - 1B:	400	450
° 4M - II (5 days)	500	550
° 4M - II (3.5 days)	500	550
On-site Training Courses (1) from the MTM Association		
° MTM - 1A:	$8,000	$8,500
° MTM - 1B:	4,500	5,000
° 4M - II (5 days)	5,000	5,500
° 4M - II (3.5 days)	4,000	4,500
Programmed Instruction (6) Annual Lease		
° MTM-1	3,000	3,200
° 4M	2,000	2,200
4M System Prices (2)(3)		
° IIA: DATA GENERAL	$36,000	$36,500
° IIA: IBM CICS or IMS	39,000	39,500
° IIA: DEC VAX 11/780	39,000	39,500
° IIA: PRIME	39,000	39,500
° IIA: IBM PCXT/AT	39,000	39,500
° IIB: IBM SYSTEM 34/36	36,000	36,500
° IIB: IBM OS or DOS	39,000	39,500
° IIB: IBM SYSTEM 38	39,000	39,500
° IIB: UNIVAC 1100 90/30	39,000	39,500
° IIB: HP 3000	39,000	39,500
2M System Prices (2)		
° CORE PROGRAM	$19,000	$19,500
° MTM-UAS DATA SET	100	600
° MTM-V, C, M, and MEK	800	1,300

NOTES: (1) Cost stated is for training of up to seven analysts. Each additional analyst (over seven) shall cost the amount shown for the Public Training Courses.
(2) Includes training and installation.

NOTES continued on the following page.

(3) All prices are for the initial CPU and/or PC site. Additional CPUs and/or PC sites may be sold at a reduced price.

(4) Additional entities must pay an access charge of 33.3% of the total system price.

(5) MTM-UAS, V, C, M, and MEK are only available to authorized users of the respective manual system.

(6) Costs stated are for the first year and the initial site.

COMPLIANCE WITH MIL STD 1567A:

The MTM-1/4M predetermined time systems are in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operational level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.
- A record of observed or predetermined time system time values used in determining the final standard time.
- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MTM-1 predetermined time system in conjunction with 4M. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- System is flexible.
- Standard data can be developed.
- Updates are provided frequently.
- Accurate.
- Human error eliminated.
- Easy to learn and apply.
- Easy to maintain.
- MTM Association holds a user's conference once a year.
- Faster than and as accurate as manual MTM-1.
- Many reports can be generated.
- Saves on writing, typing, and filing.
- Standards are auditable.
- MTM provides updates.
- Very minute - requires a lot of work to get to a particular pattern. Is somewhat cumbersome.

SYSTEM USERS:

Because of the large number of users and the fact that MTM-1 is a public system, the system vendor was unable to provide users by manufacturing type.

The MTM-1/4M system is currently being used in 128 plants which represent a variety of industries including:

- Defense
- Aerospace
- Electronic
- Medical
- Appliances
- Cosmetics

REFERENCE SOURCE:

MTM Association

MTM-2, ADAM

CONTACT: Dirk Rauglas, Dir.-Research & Tech. Sup.
COMPANY: MTM Association
ADDRESS: 1411 Peterson Avenue, Park Ridge, IL 60068
PHONE: (312) 823-7120

SYSTEM HISTORY:

In the development of **MTM-2**, research material was provided principally by the MTM Data Group in Sweden. MTM analyses from different industries and work areas were collected, checked, and then processed on a computer programmed to yield information about motion sequences and frequencies. The Swedish sample contained approximately 14,000 motions. Further analyses of sample patterns were obtained from the U.S. (about 5,000 motions) and from the U.K. (about 3,000 motions).

Research findings revealed that two main motion sequences offer the best basis for the combination of data. These sequences include a REACH, GRASP, RELEASE sequence and a MOVE, or MOVE and POSITION sequence. MTM-2 was approved by the International MTM Directorate in 1965, and in 1970 was approved by the U.S./Canada MTM Association.

SYSTEM DESCRIPTION:

The **MTM-2** predetermined time system may be defined as a synthesized system of MTM data on the second generic level based exclusively on MTM-1 single motions and motion sequence combinations. The elements employ an alphanumeric coding system.

There are nine categories of manual motions with 39 time values. The nine motion categories are:

MOTION	SYMBOL
Get	G
Put	P
Apply Pressure	A
Regrasp	R
Eye Action	E
Crank	C
Step	S
Foot Motion	F
Bend and Arise	B

MTM-2 has a smaller number of distance ranges and cases of control as compared to MTM-1. Therefore, the principal advantage of MTM-2 is its speed of application which is generally considered to be twice that of MTM-1.

ADAM is an on-line interactive system for creating and maintaining labor standards and standard data. ADAM was designed to incorporate, in any combination, the following MTM Systems:

- MTM-2
- MTM-UAS
- MTM-V
- MTM-C
- MTM-MEK

In addition, ADAM will accept and apply data developed from any other source such as time study or standard data.

SYSTEM APPLICATION:

MTM-2 can be applied manually or by computer. The manual application consists of using the data contained on the MTM-2 Data Card for elemental, standard, and/or multilevel data development. The general procedures employed in standards development are:

- Observe the operation. If visualized, the method must be verified by actual shop floor observation.

- Document detailed information about the operation including operation location, operators, part, manual, equipment, and quality requirements.

- Analyze the operation to identify and classify all the motions or motion sequences required for performing the operation and to account for right and left hand motions made simultaneously. In the case of simultaneous motions, the greater time of the two is used.

- Record the motions using the proper MTM conventions for the system being used and document them on the MTM Activity Analysis Forms.

- Assign Time Values (TMUs) to the motions by entering the proper times from the MTM Data Card.

- Add up the time values to obtain the total time required for the operation studied. The time obtained will be the time required for an operator of average skill working with average effort.

- Add the required allowances such as personal, fatigue, unavoidable delay, etc.

- Validate and apply the standard.

ADAM, the automated data application and maintenance program, utilizes the standard MTM-2 notations and applies MTM-2 rules.

The primary features of ADAM are:

- **System Setup Options**: have been provided to allow the user to customize keyboard control.

- **User Variable Options**: have been provided to allow the user to customize the ADAM installation to meet his specific needs.

- **Simplified Input Effort**: has been achieved through the use of free-format input.

- **User-Defined Elements**: are input by keying in the element code, element time, and element description.

- **Immediate Error Detection**: is provided by routines which check each entry for validity.

- **Internal Time Calculations:** are handled by identifying all manual elements which are internal to a machine cycle. ADAM performs the necessary analysis and computes the total time by applying the proper manual and process allowances to each element.

- **Data Storage:** is accomplished by a single key stroke followed by inputting an element code of up to 20 characters and a user-created element description.

- **Multilevel Data**: is supported to higher data levels.

- **Formula Application:** is fully supported by ADAM.

- **Data Base Maintenance:** is supported through editing routines which allow the analyst to get an element; modify, remove or insert data to the element; and subsequently save the element. A Mass Update Program allows the analyst to update all standards effected by editing.

- **Data Base Review:** allows the user to view portions of or the entire data base.

- **Activity Log:** function provides the user with a complete listing of all changes made to the data base.

According to the system vendor, the application time for manual MTM-2 is conservatively estimated to be 150 times the length of the cycle when the cycle is non-repetitive and includes method documentation. When applied by computer using the ADAM software package, the application time is five to 10 times faster.

MTM-2 has been used in a wide variety of applications including: metal-working and manufacturing industries; electrical and electronic-component assemblies; office and clerical applications; and other types of businesses and industry. The MTM Association states that the MTM-2 system is most applicable to **highly repetitive** work **with variations** from cycle to cycle and **to short-cycle** lengths in the one-to-five-minute range.

ADAM is currently available using the following hardware configurations:

- Apple II Plus
- Apple IIE
- Apple III
- IBM PC, XT, or compatibles
- TI Professional Computer

TRAINING/TECHNICAL ASSISTANCE:

A lecture approach is used in training individuals in the application of MTM-2. Training is available from four sources:

- The MTM Association
- MTM-licensed instructors who are self-employed
- MTM-licensed instructors who are employed by consulting firms
- MTM-licensed instructors who are employed by private or public-sector companies

The MTM Association determines analyst and instructor training requirements, maintains certification, and conducts update examinations to assure analyst and instructor competence. Recertification is required every three years.

Two MTM-2 Training Courses are available:

- **MTM-2A**: BLUE CARD™ certification in MTM-1 is a prerequisite. A 40-hour (one-week) course covering the theory and application of MTM-2. Opportunity for laboratory instruction and practice in the use of MTM-2 data is provided. Blue Card™ certification in MTM-2 is issued following successful completion of a written certification examination.

- **MTM-2B**: No prerequisite. A 64-hour (eight-day) course containing 24 hours (three days) of methods improvement and work-simplification training with relation to MTM. An appreciation of MTM-1 is also provided. The remaining 40 hours (one week) is identical to MTM-2A. Blue Card™ certification in MTM-2 is issued following successful completion of a written certification examination.

Blue Card™ certification is only issued following completion of MTM Association approved training courses.

SYSTEM COSTS:

The costs associated with the MTM-2 and ADAM systems are shown in the table below:

COST CATEGORY	LIST PRICE MTM ASSOC. MEMBERS	LIST PRICE NON-MEMBERS
Public Training Courses from the MTM Association		
° MTM-2A	$ 400	$ 450
° MTM-2B	600	650
On-Site Training Courses (1) from the MTM Association		
° MTM-2A	5,000	5,500
° MTM-2B	6,000	6,500
MTM-2 Instructor Seminar and Exam	700	—
MTM-2 Annual Instructor License	250	—
ADAM System Prices (2) (3)		
° Core Program	18,000	18,500
° MTM-2 Data Set	3,000	—
° MTM-UAS Data Set	1,000	—
° MTM-V, C & MEK Data Set (4)	N/C	—

NOTES:

(1) Costs stated include training for up to seven analysts. Each additional analyst (over seven) shall cost the amount shown for the Public Training Course.

(2) All prices are for the original installation site. Additional sites may be sold at a reduced price.

(3) One day of assistance is included in the price of the ADAM program at the original site. Additional assistance is available at a cost of $800 per day.

(4) MTM-V, MTM-C and MTM-MEK Data Sets are available only to licensed users of the corresponding manual system.

COMPLIANCE WITH MIL STD 1567A:

The MTM-2 predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.
- A record of observed or predetermined time system time values used in determining the final standard time.
- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MTM-2 predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- System is easily learned and applied.

- Computerized application provides improved speed, accuracy and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" scenarios.

- Computerized system will accept and manipulate data developed utilizing other work measurement systems or techniques.

- Past user support provided by the system vendor has been exceptional.

- The system generates several types of informational reports for use by management personnel.

- The computer program is written in Pascal and cannot be interfaced with other systems; however, an interface program is currently being developed by the system vendor.

- Use of the system requires a fundamental knowledge of computers.

SYSTEM USERS:

Because of the large number of users and the fact that MTM-2 is a public system, the system vendor was unable to provide users by manufacturing type. The MTM-2/ADAM system is currently being used in 32 plants which represent a variety of industries as follows:

- Electronic
- Defense
- Computer
- Medical
- Finance
- Aerospace

REFERENCE SOURCE:

MTM Association.

MTM-3

CONTACT: Dirk Rauglas, Dir.-Research & Tech. Sup.
COMPANY: MTM Association
ADDRESS: 1411 Peterson Avenue, Park Ridge, IL 60068
PHONE: (312) 823-7120

SYSTEM HISTORY:

The **MTM-3** predetermined time system was developed by the Swedish MTM Association with assistance provided by both the United Kingdom and Finnish groups. Development began in 1967 and the system was approved by the International MTM Directorate in 1970.

The primary objective of the system is to cover low-repetition, long-cycle work.

SYSTEM DESCRIPTION:

According to the system vendor, the **MTM-3** predetermined time system may be defined as a synthesized system of MTM data based on MTM-1 motion sequences or averaged individual motions.

There are four categories of manual motions as follows:

MOTION	SYMBOL
Handle	H
Transport	T
Step and Foot Motion	SF
Bend and Arise	B

Two of these motions, HANDLE and TRANSPORT, have variable categories, case and distance. Only 10 time values appear on the MTM-3 Data Card, ranging in value from 7 TMU to 61 TMU.

SYSTEM APPLICATION:

MTM-3 is an entirely manual system which utilizes an MTM-3 Data Card and Standard Data as its mode of standards development.

The methodology used to apply the MTM-3 system to develop elemental, standard, and/or multilevel data is as follows:

- Observe and document the operation being performed. If visualized, the method must be verified by actual shop floor observation.

- Secure complete and detailed information about the operation, including the identification of the operation, tools, workplace layout, and conditions.

- Analyze the operation to identify and classify all left/right hand motions or motion sequences required for performing the operation and identify simultaneous motions. In the case of simultaneous motions, the greater time of the two is used.

- Record the motions using the proper MTM conventions for the system being used and document them on the MTM Activity Analysis Forms.

- Assign Time Values (TMUs) to the motions by entering the proper times from the MTM Data Card.

- Add up the time values to obtain the total time required for the operation studied. The time obtained will be the time required for an operator of average skill working with average effort.

- Add the required allowances such as personal, fatigue, unavoidable delay, etc.

- Validate and apply the standard.

According to the system vendor, the application of MTM-3 has been conservatively estimated to be 50 times the length of the cycle when the cycle is non-repetitive and includes method documentation.

MTM-3 has been used in a wide variety of applications including: metalworking and manufacturing industries; electrical and electronic-component assemblies; office and clerical applications; and other types of businesses and industry. The MTM Association states that the MTM-3 system is most applicable to **non-repetitive** work with **variations** and cycle lengths in the four-to-15-minute range.

TRAINING/TECHNICAL ASSISTANCE:

Both lecture and self-paced programmed instruction formats are available for MTM-3 learning. Training is available from four sources of licensed MTM instructors as follows:

- MTM Association
- Self-employed
- Consulting firms
- Private or public-sector companies

The MTM Association determines analyst and instructor-training requirements, maintains certification, and conducts update examinations to assure analyst and instructor competence.

MTM-2 certification is a prerequisite for MTM-3 certification. Applicators receive a 24-hour (three-day) course covering the theory and application of the MTM-3 system. Blue Card™ certification is only issued following completion of MTM-Association-approved training courses. Applicators and instructors are retested on a three-year cycle.

SYSTEM COSTS:

The costs associated with the MTM-3 system are shown in the following table:

COST CATEGORY	LIST PRICE	
	MTM ASSOC. MEMBERS	NON-MEMBERS
Public Training Course	$ 300	$ 350
On-Site Training Course(1)	4500	5000
Instructor Seminar and Exam	600	---
Annual Instructor License	250	---

NOTES: (1) Costs stated include training for up to seven analysts. Each additional analyst (over seven) shall cost the amount shown for the Public Training Course.

(2) Costs listed are those charged by the MTM Association.

COMPLIANCE WITH MIL STD 1567A:

The MTM-3 predetermined time system is in compliance with the specific requirements set forth in MIL.STD.1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Since MTM-3 is a public system, the MTM Association was unable to provide any users of the system. Therefore, no strengths and weaknesses could be identified.

SYSTEM USERS:

Since MTM-3 is a public system, the MTM Association is unable to provide comprehensive records of all users.

REFERENCE SOURCE:

MTM Association

MTM-MEK

CONTACT: Dirk Rauglas, Dir.-Research & Tech. Sup.
COMPANY: MTM Association
ADDRESS: 1411 Peterson Avenue, Park Ridge, IL 60068
PHONE: (312) 823-7120

SYSTEM HISTORY:

The **MTM-MEK** predetermined time system was developed by a consortium brought together by the German MTM Association, Swiss MTM Association, and Austrian MTM Group. MTM-MEK was developed from MTM-1 utilizing statistical analysis combined with conventional standard data techniques. The system is suited for the measurement of one-of-a-kind and small-lot production. Development of the system occurred during the period of 1975 through 1982.

SYSTEM DESCRIPTION:

MTM-MEK is a two-level data system developed specifically for the measurement of any activity that has the characteristics of one-of-a-kind or small-lot production. The statistical concepts utilized in developing MTM-MEK preclude the need to develop organized methods to accurately apply the system. This allows for the development of both preproduction and production standards in environments where work organization is minimal or nonexistent.

MTM-MEK can be used to analyze all manual activities as long as the following characteristic requirements of a low methods level are met:

- The task is not highly repetitive or highly organized. The activity may contain similar elements demanding differing methods. The method used to perform a given operation will normally vary from cycle to cycle.

- The workplace, tools and equipment used must be universal in character.

- The task, being complex in nature, requires a high degree of employee training, while the lack of a specific method to accomplish the task requires a high degree of versatility on the part of the operator.

In addition, MTM-MEK is specifically applicable:

- As an analyzing system.

- As a method for establishing preproduction labor standards from drawings and bills of material.

- To customized products.

- As an analyzing system for developing standard data blocks.

- To activities with ongoing methods variation.

SYSTEM APPLICATION:

MTM-MEK, rather than focusing on an exact knowledge of the motion sequence involved in an activity, centers on the peripheral conditions under which the motion sequence takes place.

It is therefore not stated how complicated a motion sequence is, rather only that it takes place. The motion sequence is represented by coding indicating how exact the sequence is, over what distance range it takes place, and how much weight or bulkiness is involved. These same variables are available during planning analysis, thereby allowing for the development of preproduction standards. When preproduction standards are developed, they must be verified by actual shop floor observation.

MTM-MEK consists of 51 time values in the following categories:

- Get and Place
- Handle Tool
- Place
- Operate
- Motion Cycles
- Fasten or Loosen
- Body Motions
- Visual Control

MTM-MEK can be applied using the following techniques:

- Manual application through the use of the MTM-MEK Data Card.

- Automated application through the use of an MTM-MEK Data Set incorporated into 4M, 2M or ADAM.

An example of an operation analyzed using MTM-MEK is presented below:

No.	Description	Reference	Element TMU	Occurrence per Cycle	TMU per Cycle
1	Assemble Flange and Packing				
	Get/Place Flange to Bench	KAA4	120	1	120
	Get/Place Packing to Flange	KAB4	160	1	160
	Align Pinhole Image	KPB1	40	1	40
	Seat Flange	KAB3	90	1	90
	Align Flange	KPB1	40	1	40
2	Secure with 4 Bolts				
	Assemble Bolts	KA-SED	490	4	1960
		KEH4	120	1	120
	and Obtain Nuts	KET4	70	2	140
	Get/Place Washers	KAB3	90	4	360
	Tighten Diagonally	KA-SEH	190	4	760

Total TMU Per Cycle	3790
Allowances 15 %	4359
Standard Hours Per 1 Unit	.04359
Units Per Hour	22.94

According to the system vendor, MTM-MEK has been found to be from 16 to 50 times faster to apply than MTM-1. Application times range from five to 15 times the cycle time, depending on the amount of MEK Standard Data Blocks utilized. The system vendor states that, to obtain the system's stated accuracy, it is best applied to operations with cycle times of 21.3 minutes or longer.

TRAINING/TECHNICAL ASSISTANCE:

Lecture, demonstration, and practical exercises are the main approach of MTM-MEK training. Training is available from the MTM Association or from licensed instructors who are employees of firms licensed to use the MTM-MEK system.

Certification in any of the other MTM systems is a prerequisite to MTM-MEK training. Certification in MTM-MEK requires successful completion of a 40-hour (five-day) course and passing a written final examination. Certification is performed solely by the MTM Association.

The MTM Association determines analyst and instructor training requirements, maintains certification, and conducts update examinations to ensure analyst and instructor competence once every three years.

SYSTEM COSTS:

The costs associated with the MTM-MEK system are shown in the following table:

COST CATEGORY	LIST PRICE	
	MTM ASSOC. MEMBERS	NON-MEMBERS
MTM-MEK, Manual System (1)	$9,000	$9,500
On-Site Training Course (1)	5,000	5,500
Instructor Training and Exam	700	—
Annual Instructor License	250	--

NOTE: (1) Costs stated include training for up to seven analysts.

COMPLIANCE WITH MIL STD 1567A:

The MTM-MEK predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.
- A record of observed or predetermined time system time values used in determining the final standard time.
- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MTM-MEK predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- System is accurate for long-cycle, low-repetition tasks.

- Fast application time.
- Easy to learn and apply.
- Cost-effective.
- Easy to audit.
- MTM Association provides user conferences.
- Allows for variations in job conditions.
- Computer descriptions lose some detail as more work is combined into an element.
- Need more actual examples in the training manual.

NOTE: It was found that many companies are using 4M, MTM-UAS, and MTM-MEK as complementary systems with 4M for short-cycle, UAS for medium-cycle and MEK for long-cycle, low-repetition jobs.

SYSTEM USERS:

MTM-MEK has been or is being used in 19 different companies representing a variety of industries including:

- Aerospace
- Defense
- Railroad

REFERENCE SOURCE:

MTM Association

MTM-UAS

CONTACT: Dirk Rauglas, Dir.-Research & Tech. Sup.
COMPANY: MTM Association
ADDRESS: 1411 Peterson Avenue, Park Ridge, IL 60068
PHONE: (312) 823-7120

SYSTEM HISTORY:

MTM-UAS (Universal Analyzing System) was developed by a consortium of members from the German MTM Association, Swiss MTM Association, and the Austrian MTM Group during the years 1975-1982.

The original data was developed from MTM-1 analyses of operations filmed in numerous plants. The operations were chosen to insure that typical characteristics of batch production were present.

The time elements were developed comprised of well-defined motion sequences. All time elements contain the required "Auxiliary Motions," (e.g., Transfer Grasp, Regrasp, and Disengage).

MTM-UAS was developed to meet the need for supplying effective work measurement to the area of batch production.

SYSTEM DESCRIPTION:

MTM-UAS is a system designed for measurement of **batch production** activities with the characteristics of similar tasks, designed workstations, organized work levels, detailed operator instructions, and well-trained operators. The system allows for the variability inherent in the batch production environment. MTM-UAS can be applied across industries and across activities.

MTM-UAS has been developed in two levels of data. **Level I** is public data and consists of 77 time values in the following motion categories:

- Get and Place
- Place
- Handle Tool
- Operate
- Motion Cycles
- Body Motions
- Visual Control

Level II is proprietary and consists of data sets developed from Level I data. There are 494 time values relating to the following activities:

- Fastening Operations
- Sealing/Plugging Operations
- Assemble Standard Parts
- Transporting Operations
- Marking Operations
- Adhering/Bonding Operations
- Cleaning Operations
- Preparing Activities
- Apply Agents
- Assemble Cables
- Clipping Operations

SYSTEM APPLICATION:

MTM-UAS may be applied in developing standard data and for direct analysis. MTM-UAS may be used in combination with data developed from other sources. The system is applied using the following techniques:

- Manual application through the use of the MTM-UAS Data Card.
- Automated application of MTM-UAS Data Sets can be accomplished using 4M, 2M, or ADAM, three computerized systems developed and supported by the MTM Association.

An example operation analysis using manual MTM-UAS is shown on the following page.

According to the system vendor, the MTM-UAS system when applied manually has been determined to be a minimum of eight times faster to apply than MTM-1, which results in application speeds of a maximum of 30 times the length of the activity being studied, including method documentation. In practice, it has been found that, through the use of standard data techniques, significant reductions in application times have been realized. When MTM-UAS data is combined with 4M, 2M or ADAM, standard development can be accomplished in equal or less time than the operation being analyzed requires.

MTM ASSOCIATION FOR STANDARDS AND RESEARCH

MTM OPERATION ANALYSIS MANUAL UAS

099123 010

Sheet 1 of 1

DEPARTMENT:	ANALYST:	DATE:
1009	MO	08/01/84

No.	Description	Reference	Element TMU	Occurrence per Cycle	TMU per Cycle
1	Assemble Brace and Bit				
	Assemble Chuck to Pawl	AC2	55		55
	Move Brace to Work Area	AA2	35		35
	Assemble Chuck to Brace	AC1	40		40
	Turn Down	ZB1	10	8	80
	Assemble Bit to Brace	AC2	55		55
	Close Chuck	BA1	10		10
	Turn Down	ZB1	10	6	60
	Get Brace by Handle	AA2	35		35
	Final Tighten	ZD	20		20
	Aside Brace and Bit	PA1	10		10
				TOTAL TMU PER CYCLE	400
				ALLOWANCES 15 %	460
				STANDARD HOURS PER 1 UNIT	.00460
				UNITS PER HOUR	217.39

MTMA 2803-77

The system vendor states that MTM-UAS is universally applicable to activities in which the following characteristics of **batch production** are present:

- Similar tasks
- Workplaces specifically designed for the task
- Good levels of work organization
- Detailed instructions
- Well-trained operators

Additionally, the MTM-UAS system is best suited for **repetitive** work **with variations** from cycle to cycle or with variations in workplace setup and cycle lengths in the two-to-seven-minute range.

TRAINING/TECHNICAL ASSISTANCE:

A lecture course is the approach used in training individuals in the application of MTM-UAS. Training is available from four sources:

- MTM Association
- MTM-licensed instructors who are self-employed
- MTM-licensed instructors who are employed by consulting firms
- MTM-licensed instructors who are employed by private or public-sector companies

Two MTM-UAS training courses are available:

- **MTM-UAS-A**: A 32-hour (four-day) course covering the theory and application of the system. Opportunity for laboratory instruction and practice in the use of UAS is provided. Blue Card™ certification in MTM-UAS is issued following successful completion of a written certification examination.

- **MTM-UAS-B:** A 56-hour (seven-day) course containing 24 hours (three days) of methods-improvement and work-simplification training with relation to UAS. An appreciation of MTM-1 is also provided. The remaining 32 hours are identical to UAS-A. Blue Card™ certification in MTM-UAS is issued following successful completion of a written certification examination.

The MTM Association determines analyst and instructor-training requirements, maintains certification, and conducts update examinations to ensure analyst and instructor competence once every three years. Blue Card™ certification is issued only upon completion of an MTM-Association-approved training course.

SYSTEM COSTS:

The costs associated with the MTM-UAS system are shown in the table below.

COST CATEGORY	LIST PRICE	
	MTM ASSOC. MEMBERS	NON-MEMBERS
MTM-UAS Level II, Manual System (1)	$2,000	$2,500
Public Training Courses		
° MTM-UAS-A	400	450
° MTM-UAS-B	600	650
On-Site Training Courses (1)		
° MTM-UAS-A	5,000	5,500
° MTM-UAS-B	6,000	6,500
Instructor Training and Exam	650	—
Annual Instructor License	250	—

NOTES: (1) Costs stated include training for up to seven analysts. Each additional analyst (over seven) shall cost the amount shown for the Public Training Courses.

(2) Costs stated are for courses taught by the MTM Association.

COMPLIANCE WITH MIL STD 1567A:

The MTM-UAS predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.
- A record of observed or predetermined time system time values used in determining the final standard time.
- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MTM-UAS predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- System is accurate.
- Fast application time.
- Easy to learn and apply.

- Cost-effective.
- Easy to audit.
- MTM Association provides user conferences.
- Can be applied to a variety of applications.
- Computer descriptions lose some detail as more work is combined into an element (i.e., as compared to 4M).

NOTE: It was found that many companies are using 4M, MTM-UAS, and MTM-MEK as complementary systems, with 4M for short-cycle, UAS for medium-cycle and MEK for long-cycle, low-repetition jobs.

SYSTEM USERS:

MTM-UAS has been or is being used in 25 different companies representing a variety of industries including:

- Aerospace
- Defense
- Medical
- Electronic

REFERENCE SOURCE:

MTM Association

MTM-V

CONTACT: Dirk Rauglas, Dir.-Research & Tech. Sup.
COMPANY: MTM Association
ADDRESS: 1411 Peterson Avenue, Park Ridge, IL 60068
PHONE: (312) 823-7120

SYSTEM HISTORY:

MTM-V was developed by a consortium of organizations involved in a diversity of machining operations and is based on MTM-1. The development of MTM-V was under the supervision of the Swedish MTM Association and occurred during the period of 1967-1969.

SYSTEM DESCRIPTION:

MTM-V is a data system developed to provide time standards for the manual portions of machine-shop operations. Motions involved in setup and production runs of machines are covered by 12 motion categories. These categories are:

- HO - Handle Object
- HH - Handle Hand Tool
- HL - Handle Latch
- SK - Rotate by Hand
- GR - Inspect
- MR - Use Marking Tools
- BE - Blow or Brush off Equipment
- MA - Machine Adjustment
- FL - Fasten/Loosen with Hand Tool
- MT - Use Measuring Tool
- KO - Use Gaging Tools
- KP - Couple to Hoist

Light, medium, and heavy manufacturing operations are covered by the MTM-V system. MTM-V can be applied to all work within the following limits:

- The size of the workpiece must not be so small as to require an aid, such as tweezers, for handling.

- The size of the workpiece must not be so large that one man cannot guide and direct the workpiece when it hangs from an overhead crane or similar device.

- The weight of the workpiece must be such that one employee working with an overhead crane or similar device can handle the piece without assistance.

SYSTEM APPLICATION:

MTM-V can be used to develop elemental, standard, and/or multilevel data. MTM-V may be used in combination with data developed from other sources and is applied using the following techniques:

- Manual application through the use of the MTM-V Data Card.

- Automated application through the use of MTM-V Data Sets incorporated into the 4M, 2M, and ADAM computerized systems. (A detailed discussion of the 4M, 2M, and ADAM systems can be found in the MTM-1, and MTM-2 system write-ups, respectively.)

An example operation analysis using manual MTM-V is shown below:

- MARK AND DRILL OPERATION

DESCRIPTION	F	MOTION	TMU
Mark workpiece		MRA 30	190
Drill into spindle		HO2	40
Put part into vise		HO2	40
Crank down drill		MAC2	50
Set part to drill point		MAFO	30
Tighten vise by hand		SKCO	100
Pin to handle - strike - tighten		FLA20	110
Additional strikes		FLA10	70
Start machine		MAA2	20
Lower drill < 2 revolutions		MAC2	50
Process time		PT	—
Stop machine		MAA2	20
Pin to handle - strike - loosen		FLA20	110
Open vise & remove piece		SKA2	70
Remove drill - prying tool		FLA22	140
Brush chips away		BED30	280
Lift wedge		HO2	40
		TOTAL TMU:	1360

According to the system vendor, MTM-V has been shown to be 23 times faster to apply than MTM-1 and results in theoretical application and method documentation times of eight to 10 times the cycle time involved. When MTM-V data is used with 4M, 2M or ADAM, the standard development activity can be accomplished in equal to or less time than the operation being analyzed.

The MTM-V system can be applied to **long-cycle, non-repetitive** jobs **with variations** as found in a machine-shop environment.

TRAINING/TECHNICAL ASSISTANCE:

Both lecture and programmed instruction methods are available for MTM-V learning. Training is available from the MTM Association and licensed instructors who are employees of firms licensed to use MTM-V.

Certification in MTM-V requires successful completion of a 40-hour (five-day) training course and passing a written certification examination. Certification is provided solely by the MTM Association.

The MTM Association determines analyst and instructor training requirments, maintains certification, and conducts update examinations to ensure analyst and instructor competence once every three years.

SYSTEM COSTS:

The costs associated with the MTM-V system are shown in the table below.

COST CATEGORY	LIST PRICE	
	MTM ASSOC. MEMBERS	NON-MEMBERS
MTM-V - Manual System (1)	$9,000	$9,500
Programmed Instruction Annual Lease (2)	2,000	2,200
On-Site Training Course (1)	5,000	5,500
Instructor Training and Exam	600	—
Annual Instructor License	250	—

NOTES: (1) Costs stated include training for up to seven analysts.

(2) Costs stated are for the first year and for the initial site only.

COMPLIANCE WITH MIL STD 1567A:

The MTM-V predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.
- A record of observed or predetermined time system time values used in determining the final standard time.
- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MTM-V predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- Easy to use.
- Cost-effective.
- Provides accurate standards.
- Must use another method for applications not directly related to the machine (i.e., go get blueprint or tools).

SYSTEM USERS:

MTM-V is to be used for the manual portions of machining operations and has been or is being used in 26 companies representing a variety of industries.

REFERENCE SOURCE:

MTM Association

MTM-TE

CONTACT: Dirk Rauglas, Dir.-Research & Tech. Sup.
COMPANY: MTM Association
ADDRESS: 1411 Peterson Avenue, Park Ridge, IL 60068
PHONE: (312) 823-7120

SYSTEM HISTORY:

MTM-TE was developed in the United States from 1980 to 1985 by a consortium of companies knowledgeable in both work measurement techniques and electronic test procedures and equipment, and is based on MTM-1.

SYSTEM DESCRIPTION:

MTM-TE is a two-level standard data system used to establish standards in the electronic testing environment. Typical motion patterns appropriate for set-up, testing, and teardown of units under test are covered. The two levels of data contained in the MTM-TE system are:

LEVEL 1	LEVEL 2
° Get	° Get and Place
° Move	° Read and Identify
° Body Motions	° Adjust
° Identify	° Body Motions
° Miscellaneous	° Waiting

Level 3 data is also available in the form of synthesized Level 1 elements. Users can establish Level 3 data based on the methodology and frequencies encountered at their facility.

The MTM-TE system covers basic test, repair and retest operations.

SYSTEM APPLICATION:

MTM-TE may be applied to develop elemental, standard, and/or multilevel data. The system is applied using the following techniques:

- Manual application is through the use of the MTM-TE Data Card.

- Automated application is through the use of the 4M and 2M systems.

The system vendor states that the MTM-TE system is applicable to **repetitive electronic test routines** that occur in two-to-10-minute cycle lengths. In addition, an analyst who is familiar with test operations and related equipment will find the three levels of data easy to apply directly to the detailed test procedures. The data, however, does not cover "troubleshoot" relative to electronic test operations. The system does provide guidelines for investigation and recommendations for work measurement for this activity.

TRAINING/TECHNICAL ASSISTANCE:

Lecture, demonstration, and practice exercises are the major training procedures. Employees of the MTM Association are currently the only authorized instructors, and training in MTM-TE is only available to employees of firms licensed to use MTM-TE.

Certification requires successful completion of a 32-hour (four-day) course and passing of a final examination. Certification is provided solely by the MTM Association.

The MTM Association determines analyst and instructor-training requirements, maintains certification, and conducts update examinations to assure analyst and instructor competence once every three years.

SYSTEM COSTS:

System-related costs were not provided by the vendor.

COMPLIANCE WITH MIL STD 1567A:

The MTM-TE predetermined time system is in compliance with the specific requirements set forth in MIL.STD.1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of $\pm$10% with a 90% or greater confidence at the operation level.

- Documentation of an operations analysis.

- A record of standard practice or method followed when the standard was developed.

- A record of rating or leveling.

- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MTM-TE predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- Data was developed from observations and previously developed data in a broad range of industrial applications and was verified using MTM-1.

- There are three levels of data from which a user can determine which level is best applicable to his needs.

- The computerized application provides improved speeds, accuracy and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" methods-improvement scenarios.

- Optimum application of the standard data requires that the analyst be familiar with electronic test equipment and operations.

- The system data does not cover automated or computerized electronic test activities.

- The third level of data requires initial validation of processes to ensure that the data included in the standard is consistent with the operation being analyzed.

SYSTEM USERS:

MTM-TE is being used in eight different companies and is used only within the electronic testing area.

REFERENCE SOURCE:

MTM Association

CONTACT: Dirk Rauglas, Dir.-Research & Tech. Sup.
COMPANY: MTM Association
ADDRESS: 1411 Peterson Avenue, Park Ridge, IL 60068
PHONE: (312) 823-7120

SYSTEM HISTORY:

MTM-M was developed as a result of a consortium project involving the MTM Association Magnification Consortium and the Department of Industrial Engineering at the University of Michigan, conducted during the period of 1968 through 1972.

MTM-M was developed from data collected from the analysis of 20 case studies in six industrial firms covering 48 operation cycles and is contained in a computer data bank consisting of 5,000 lines of "sequence" data.

The data was then analyzed and, through the use of statistical techniques, arranged in tabular data tables for ease of application, supported by regression equations.

SYSTEM DESCRIPTION:

The **MTM-M** predetermined time system is defined by its vendor as a second-level functional system of original data, designed for the analysis and measurement of **manual assembly work** performed under **stereoscopic magnification** of 5-to 30-power.

Elemental data contained in the MTM-M system is directly tied to the portion of the visual fields concerned and the hand tools employed, with mnemonic alphabetical coding expressing the variables. Analysis is performed by utilizing a "direction-of-motion-travel" concept. Consequently, the tables of data are named for motion direction rather than for the actual motions performed during the assembly.

MTM-M consists of four major tables and one subtable which contains all of the data necessary for system application.

TABLE II (Inside-to-Inside): Contains time data for motions starting and ending inside the microscopic field of view.

TABLE IO (Inside-to-Outside): Contains time data for motions starting inside and ending outside the microscopic field of view.

TABLE OO (Outside-to-Outside): Contains time data for motions starting and ending outside the microscopic field of view.

TABLE OI (Outside-to-Inside): Contains time data for motions starting outside and ending inside the microscopic field of view.

TABLE IF (Infield-to-Final-Target): Contains time data for motions continuing inside the microscopic field of view and ending at the final target.

The selection of the appropriate data from the data tables is determined by considering four variables:

- **Type of Tool**: Four types of tools are provided for in the data: Grasping, Probing, Cutting, and Stripping.

- **Condition of Tool**: Tools may be either Empty or Loaded.

- **Terminating Characteristic of the Motion**: The only transporting motion is Move, since tools are always used (fingers are considered a tool). Consequently, Reaches need not be considered, and moves are terminated either by a Grasp or by a Release.

- **Distance/Tolerance Ratio**: Is defined as the ratio of the distance moved to the total clearance (tolerance) at the end of the motion. This ratio, in effect, describes the degree of difficulty of positioning at the end of the move. The data tables contain a number of ranges into which a given distance/tolerance ratio may fall.

SYSTEM APPLICATION:

MTM-M may be applied to develop elemental, standard, and/or multilevel data. The system may be applied using the following techniques:

- Manual application through the use of the MTM-M Data Card.

- Automated application through the use of MTM-4M or MTM-2M.

MTM-M is for use in developing standard times for **assembly** work performed under a **microscope** (stereoscopic) at magnifications of 5- to 30-power. The system is best suited for **short-cycle repetitive** operations.

TRAINING/TECHNICAL ASSISTANCE:

A lecture format is used for MTM-M learning. Training is available from the MTM Association and licensed instructors employed by firms who are licensed to use MTM-M. Training is only available to employees of firms licensed to use MTM-M.

Certification in the application of MTM-M requires successful completion of a 40-hour lecture, demonstration, and application course, and passing a certification examination administered by the MTM Association.

The MTM Association determines analyst and instructor training requirements, maintains certification, and conducts update examinations to assure analyst and instructor competence once every three years.

SYSTEM COSTS:

The costs associated with the MTM-M system are shown in the table below:

COST CATEGORY	LIST PRICE	
	MTM ASSOC. MEMBERS	NON-MEMBERS
MTM-M, Manual System (1)	$9,000	$9,500
On-Site Training Course (1)	5,000	5,500
Instructor Seminar and Exam	600	—
Annual Instructor License	250	--

NOTE: (1) Costs stated include training for up to seven analysts.

COMPLIANCE WITH MIL STD 1567A:

The MTM-M predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of $\pm$10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MTM-M predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- Accurate and appropriate in the application of microscopic work.

- Provides for the difference in time required to perform an operation under varied degrees of magnification.

- MTM Association training includes instruction in methods analysis specific for microscopes and in the care and use of a microscope.

- Time-consuming to use.

- Good only for magnifications of 30X or less.

SYSTEM USERS:

MTM-M is currently being used by nine companies in 15 locations and is used only for stereoscopic assembly.

REFERENCE SOURCE:

MTM Association

MANPRO™

CONTACT: Herbert R. Wilkes, President
COMPANY: Methods Management
ADDRESS: 2801 Morgan Territory Road, Clayton, CA 94517
PHONE: (415) 672-3431

SYSTEM HISTORY:

MANPRO™ was developed from micromotion films as a manual predetermined universal work-measurement system in the early 1960s. The system was further refined and computerized in the early 1970s as an in-house consulting tool. The initial computerization of MANPRO™ was done on a large scale time-sharing system. In the early 1980s, Methods Management licensed companies to utilize the system as end-users, and in 1986 the MANPRO™ system was tailored to run on IBM personal computers as a stand-alone product.

The evolution of the system was the result of the combined efforts of Methods Management personnel and computer experts, and its data bases embody 20 years of industrial and manufacturing exposure.

SYSTEM DESCRIPTION:

MANPRO™, an acronym for **MAN**ufacturing **PRO**ductivity, is a microcomputer software program and data base used to analyze and document work activities in manufacturing, fabrication, process control, test, maintenance, service and clerical environments, and to generate engineered time standards.

Methods analyses and standards development performed by utilizing the MANPRO™ system are based on the system's **Basic Motion and Assembly Data**. This set of work elements covers the majority of motions performed during general setup, material retrieval/handling, manual assembly and disassembly, tool use, and inspection activities. In addition, a variety of standard data packages, built from the Basic Motion and Assembly Data, and covering a variety of industrial activities, are available to be used during the standards development process. Standard data packages available include:

- **Mechanical and Electronic Assembly**

- **Printed Circuit Board and Wire/Cable Assembly**
- **Sheet Metal Fabrication**
- **Machining Operations**
- **Janitorial Services**
- **Large-scale Systems Integration**
- **Semiconductor Wafer Fabrication**

In addition to these work elements, the MANPRO™ system allows the user to create specialized classifications of "nonstandard" elements identified during the analysis of performed work.

The MANPRO™ system also accepts and manipulates standard data developed by utilizing other work measurement systems. Similarly, historical or estimated time elements may be entered into the system to support interim labor monitoring, while engineered standards are being developed.

Each element contained in the Basic Motion and Assembly Data and standard data packages incorporates allowances to account for work environment (normalization), and for personal, fatigue and delay considerations. Additional user-defined allowances can be added as required. These allowances can be adjusted depending upon the environment and user preference.

The MANPRO™ system utilizes four major time classifications to identify work required in performing a given activity:

- **Direct Labor**: Manual labor that directly contributes to the production of each unit of a product. Elements in this category are totaled into the overall standard time.

- **Process Time**: Machine-cycle time or process-controlled time involved in the unit production of a product. These elements are also totaled directly into the overall standard.

- **Internal Labor**: Any manual labor performed within the limits of a machine-controlled cycle. This category of time is not included in the overall standard unless the internal labor time for an activity exceeds the process time, in which case the excess time is accounted for as direct labor.

- **Setup Time**: Overhead labor expended to prepare for a job prior to actual production. This time is totaled separately from the overall per-unit standard, unless the user desires prorating the setup time on a per-unit-of-output basis.

To accommodate those types of activities which derive their times from formulas and/or tables of values, the MANPRO™ system has the capability to accept user-defined formulas. This is particularly true for machine-shop activities where the data has been "distilled" to simplify its use, using such schemes as broad material classifications, tool-bit classifications, finish and speeds/feeds groupings (including embedded safety factors), and other application rules.

In order to define standard terminology used by the user's specific industry and environment, the MANPRO™ system utilizes a **"Nomenclature Dictionary"**. A generalized data set of industrial terminology is included with the system as a base from which the user may add to and subtract from to create a customized vocabulary.

Major reports and features of the MANPRO™ system are summarized below:

- **Operation Summary** - a compilation, from individual standard method analyses, of work-center and description information, and setup and run-time standards for each operation within a part, to produce a router or traveler.

- **"What-if" Analyses - Methods Improvement** - the modification of operational sequences, insertion, and deletion of items of work, changing of factors, etc., can be analyzed and reports can be generated to show the before, after and net-change time figures for the standard.

- **Where-used Reports** - a compilation of elemental usage statistics to evaluate what the total impact editing an element would have on current standards and operations.

- **Methods Detail Report** - a detailed printout of methods sequences.

- **Summary Listings** - report which presents only the overall description and time summary for either the total standard or matching operations.

- **Batch Editing Over the Entire Standards Base** - allows for editing the universe of specific standards in a single batch edit.

SYSTEM APPLICATION:

MANPRO™, as described by its vendor, is a specialized, precise, flexible "language" which can be used to describe the sequence of events required to perform activities. The language consists of two basic components: "**verbs**," or elements of work and motion, and "**nouns**," the objects which are worked or acted upon. MANPRO™ uses the terminology "**WORK ELEMENTS**" and "**NOMENCLATURE INSERTS**," respectively. These are combined to form complete descriptive phrases which accurately document each step in the work sequence or process being analyzed. To illustrate, the following example has been prepared:

Element (verbs): Pickup and Move * to * (20-30")

+

Insert (nouns): Air-driver, Bench

=

Completed Phrase: Pickup and Move Air-driver to Bench

The resulting methods analysis is called a production "**JOB-STANDARD**." A job standard contains the step-by-step methods analyses for each element. Whether observed or visualized, the methods analysis must be verfied by actual shop floor observation.

An example MANPRO™ Analysis is shown below:

- ASSEMBLE KEY LOCK TO VIDEO CHASSIS

LINE	ELE	FACTOR	DESCRIPTION	STD-HRS
****	OPER 10	(ASSY/STN02)	(A): Assemble key lock to video chassis	
1	5	1	GET UP FROM STOOL	0.00032:
2	19	1/5	P/U AND MOVE CHASSIS TO BENCH .... >30"	0.00031:
3	14	1/5	UNWRAP OR UNBAG CHASSIS	0.00035:
4	37	1	P/U KEY LOCK, ASSEMBLE TO CHASSIS .. -20"	0.00099:
5	37	1	P/U STARWASHER, ASSEMBLE TO KEY LOCK.. -20"	0.00099:
6	23	1	P/U AND MOVE NUT TO ASSY TO KEY LOCK.. -20"	0.00058:
7	99	1	SEAT AND START THREADS OF NUT	0.00065:
8	70	20	TURN NUT (PER TURN)	0.00348:
9	63	1	P/U WRENCH & ASIDE ON COMPLETION .. -10"	0.00048:
10	71	2	TIGHTEN NUT WITH HAND-TOOL (PER TURN)	0.00058:
			SUBTOTAL:<SET= 0.00000><RUN=	0.00872>

: SETUP-TIME :	OVERALL-STD
: 0.00000 :	0.00872 Hr

In the example shown above, built from the system's basic assembly data, allowances are already factored into the standard hours. The allowances can be changed to any level desired by the user. The backup to each standard data element used is retrievable on-line, and the micromotion detail backup for each basic assembly element is provided to the user in a manual.

The MANPRO™ system is "**menu-driven**" rather than "command-driven," thereby allowing the user to select the applicable commands from a selection list (or "menu") that appears on the computer monitor screen. Methods documentation can be created by using "methods templates," which are generic "standards" that the user can create for various shop areas or product lines. All menus utilize a single-keyed mnemonic letter to make selections, and on-line help is available.

The MANPRO™ system operates on an IBM-PC/XT or similar IBM-compatible computer. Basic hardware requirements include at least one floppy-disk drive and one 10-megabyte fixed disk. A practical memory requirement is 512K bytes, as the MANPRO™ system requires approximately 384K bytes of available memory in order to execute.

The system can be applied to both **short- and long-cycle jobs,** whether **highly repetitive** with **no method variations**, or **non-repetitive with method variations.**

Although the time may vary depending upon the skill level of the user, the vendor estimates that the time required to develop a job standard using MANPRO™ is approximately equal to the time required to perform the activity being studied, assuming the method has been observed and elements documented.

For users who are already using other predetermined time systems, Methods Management has performed translations of its basic MANPRO™ system data in terms of some of the other systems. This data may be purchased as reference manuals.

TRAINING/TECHNICAL ASSISTANCE:

The vendor, Methods Management, provides on-site instruction and training for potential users and management personnel during the installation period. This on-site instruction covers the use of the system programs and the application of the MANPRO Basic Data, and includes 40 hours of instructional time.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE[1]
MANPRO™ Level - III 50-Year Software License: Includes Programs and MANPRO™ Basic Assembly	$55,000
Annual MANPRO™ License and Software for Entrance-Level Standard Data Systems (See Standard Data Modules)	6,000[2]
Yearly License and Programs to Run User's Own Data	9,000
Annual Software Maintenance and Systems Support Agreement (Subscription is optional)	1,800[3]
Standard Data Modules (Purchased with one of first two items above)[2]	
° Printed Circuit Board Assembly	9,000
° Wire Prep and Cable Harness Assembly	4,000
° Sheet metal Fabrication	5,000
° Machining, Fabrication, and Welding	10,000
° Printed Circuit Board Fabrication	7,000
° Assembly (mechanical and electrical)	NC

NOTES: (1) Installations beyond 100 miles from San Francisco will require reimbursement for expenses incurred.

(2) This permits a first-time user to be operational with standard data.

(3) System enhancements made to the MANPRO™ software, as well as updates to standard data modules, are distributed to all users subscribing to the support agreement. In addition, the support agreement provides technical support via telephone and program fixes.

(4) User discounts may apply in the following categories:

- Defense Contractors - eligible for Government Discounts on 1567A-related contracts.
- Government - Local, State and Federal
- Multiple-site Corporate Discounts
- Multiple-user Multiple-location WAN (Wide Area-shared Network)
- Single-site Multiple-user LAN (Local Area Network)

COMPLIANCE WITH MIL STD 1567A:

The MANPRO™ predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ± 10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.
- A record of observed or predetermined time system time values used in determining the final standard time.
- Provision of an audit trail down to the elemental standard time.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MANPRO™ predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- A computerized system which provides improved speed, accuracy, and consistency of application, and which enables the user to more easily

modify standards, perform mass updates, and develop and analyze "what-if" method-improvement scenarios.

- System vendor will provide standard data covering common activities in several industrial environments to purchasers of the system.

- The system will accept and manipulate data developed by utilizing other work measurement systems or techniques.

- The system generates several types of informational reports for use by management personnel.

- The system can be quickly learned, implemented and easily maintained.

- Entirely computerized - cannot be applied manually.

SYSTEM USERS:

Based on data supplied by the system vendor, a breakdown of system users by manufacturing type is as follows:

APPLICATION TYPE	NUMBER APPLICATIONS
Metal Fabrication	14
Machining Operations	8
Janitorial Services	2
Electronic Assembly	24
Large-scale Systems Integration	5
Mechanical Assembly	47
Semiconductor Wafer Fabrication	5
Semiconductor Crystal Growing	2

REFERENCE SOURCE:

Methods Management

BASIC MOST® SYSTEMS

CONTACT: Kjell B. Zandin, Senior Vice President
COMPANY: HB Maynard & Co., Inc.
ADDRESS: 235 Alpha Drive, Pittsburgh, PA 15238
PHONE: (412) 963-8100

SYSTEM HISTORY:

The development of the **Basic MOST® System** began in the late 1960s under the direction of the Swedish Division of HB Maynard and Company.

The development was the result of an extensive review of MTM data in which it was detected that similarities existed in the sequence of MTM-defined motions whenever any object was handled. It was found that the same set of basic motions were used for the same general sequence, raising questions as to whether this phenomenon could be used to develop a new way to analyze methods and to measure operations.

Over the next several years, it was determined that the movement of objects follows certain consistently repeating patterns, such as reach, grasp, move, and position. These patterns were identified and arranged as a sequence of events (or subactivities) followed in moving an object. This concept provided the basis for the MOST® sequence models.

The development initially focused on the isolation and development of models for three motion sequences that could be used to analyze and measure practically all manual work. Later, three additional sequences were developed to analyze material-handling activities which required mechanical assistance. Based on MTM data and statistical methods, a set of several index numbers was developed for use with the sequence models. Utilizing these developments, the data required to develop Basic MOST® was extracted. Application procedures were tested in a variety of industries in Sweden and Western Europe.

In 1977, the development of a computer application for Basic MOST® was initiated. Over the years, the computer system has been continually updated to its present form which allows the system to be run on mainframe, mini-, micro-, and/or personal computers.

SYSTEM DESCRIPTION:

Basic MOST® (Maynard Operation Sequence Technique) is one member of the MOST® family of predetermined time systems whose basis is to concentrate on the displacement of objects under the premise that units of work are organized for the purpose of accomplishing some useful result through the movement of objects. Basic MOST® was designed to measure activities which may **vary in method**, covering operations considered to be of average length (normally in the range of five seconds to five minutes) and which can be applied either manually or with the use of a computer.

The **primary work units** are **fundamental activities** (collections of basic motions) dealing with the movement of objects. Each of these activities are described in terms of subactivities fixed in a **sequence**. Consequently, the basic pattern of an object's movement is described by **universal sequence models** instead of random, detailed basic motions.

The system ascertains that objects are moved in only one of two ways, resulting in a different sequence of events; therefore, a separate MOST® activity sequence model applies. When tools are used, an activity sequence model is used which allows for the movement and use of a hand tool through a standard sequence of events.

The Basic MOST® technique is comprised of three basic sequence models:

- **General Move Sequence**
- **Controlled Move Sequence**
- **Tool Use Sequence**

In addition to the three basic sequence models, an equipment-handling sequence is available to analyze the movement of heavy objects which require a manually operated crane (i.e., jib crane).

The sequence models, in addition to describing the motions employed, provide the total time value for the activities by using index numbers. An index number is placed after each subactivity in the sequence and represents the time allowed for that subactivity. The tables shown on the Basic MOST® data card serve as a reference for identifying the appropriate index values.

According to the system vendor, with Basic MOST®, the analyst does not have to make "judgment" calls, thereby reducing potential variations and application errors in applying the system. In applying the system, it is essential that the workplace and method be well-documented. After completing the analysis, the system assists the analyst in identifying inefficient methods and potential improvements of the work conditions.

Basic MOST® uses an approach based on a simple construction and the grouping together of basic motions that frequently occur in sequence. In addition, the system requires the identification of only seven subactivities, with sequence models preprinted on the analysis form, requiring the analyst only to fill in the variable index numbers.

As a computerized system, it offers the major advantage of being consistent in application through the use of key words to describe methods. The method description and key words signal the computer as to which sequence model should be used and which values should be applied, thereby eliminating errors in calculations. Also, the computer system provides the ability to edit any data, work-area information, or standards that have been previously input or calculated. In addition, this provides the engineer with the ability to simulate potential improvements based on method or work-area changes.

SYSTEM APPLICATION:

Basic MOST® has the capability to be applied either manually or in a computerized form. Although the same basic principles apply, the method of application varies as follows:

- **MANUAL:**

  To apply the Basic MOST® system, the applicator must first observe and document the workplace and operation method. If visualized, the method must be verified by actual shop floor observation. Once the method has been documented, the appropriate sequence model is selected for each method step from the following:

  - General Move
  - Controlled Move
  - Tool Use

Once selected, variations in subactivities are indicated by different values selected from a fixed scale of index values and the appropriate data card as follows:

A_{10} B_6 G_3 A_{10} B_0 P_3 A_1

A_{10} - Walk six steps (Action distance)
B_6 - Bend and arise (Body motion)
G_3 - Grasp heavy object with two hands (Gain control)
A_{10} - Walk six steps (Action distance)
B_0 - No bend (Body motion)
P_3 - Place and adjust object (Placement)
A_0 - No return (Action distance)

The above example represents a "General Move" which indicates the walking of six steps, lifting of a heavy part from floor level, walking six steps back to the machine and positioning the part in the fixture.

The time value for the sequence is obtained by adding together the index numbers and multiplying the sum by 10. The standard time for the example sequence:

A_{10} B_6 G_3 A_{10} B_0 P_3 A_0 = 32 x 10 = 320 TMUs

(Note: 1 TMU (Time Measurement Unit) equals .00001 hours. In this example, the activity required approximately 11.5 seconds to complete).

Based on studies performed by the vendor, as a general rule, one hour of work can be measured with an average of 10 hours of MOST® analyst time once the method and workplace layout have been defined.

- **COMPUTER**:

To perform a Basic MOST® analysis using the computerized system, the analyst gathers work-area information and keys the information into the computer data base. Critical work-area information to be put into the computer is: (1) work-area names, locations and sizes; (2) tools and their locations; (3) objects and their locations; (4) equipment and its

location, along with appropriate process times; (5) operator(s) and starting location(s), and body motions associated with particular workplaces and the distance (in steps) between workplaces.

The activity being studied is documented in sentence format, starting with a "key word" that designates to the computer the sequence model to be used, as well as the values for selected sequence parameters. Key words, and the method descriptions, conform to basic English sentence structure and engineering terminology. Utilizing the key words and the work-area data, the computer calculates the standard time for the activity being studied.

It is the vendor's belief that the Basic MOST® computer system is two to five times faster than the manual application.

Hardware requirements for the Basic MOST® computer systems vary depending on the user's needs. Software is available for personal computers, the IBM XT, AT or compatible microcomputers, and for Digital Equipment Corporation's minicomputer systems (VAX). An IBM mainframe version is under development.

Basic MOST®, both manual and computerized, has been applied in a variety of industries including metalworking, foundries, railcar manufacturing, textiles, shipbuilding, aerospace and commercial aircraft, automotive, food processing, agricultural and construction equipment manufacturing, furniture manufacturing, and steel production.

Basic MOST® was designed to be applied to work in which the method can be defined and described, and which requires setting labor standards. Such applications can involve methods which are either **repetitive** or **non-repetitive** and **short-** or **long-cycles with** or **without variations.** However, Basic MOST® is **not recommended** to be used **for highly repetitive, short-cycle operations** or for **long-cycle**, **nonidentical operations.** (See separate write-ups on Mini MOST® and Maxi MOST®).

TRAINING/TECHNICAL ASSISTANCE:

To use the manual Basic MOST® System, the analyst must be certified by completing a 40-hour training course, which can be accomplished through a variety of training alternatives:

° A 40-hour lecture or self-paced course at one of HB Maynard's two training facilities.

° A 40-hour lecture course taught by HB Maynard personnel at the client's facility.

° A 40-hour lecture course taught by a licensed client instructor.

° A self-paced program with guidance from a licensed client instructor.

To become certified in the Basic MOST® computer system, the analyst must first be certified in manual Basic MOST® and then certified in computerized Basic MOST® by completing a 40-hour training course available through the same variety of alternatives listed above, except that all computer-system training is lecture-style.

Regardless of the training method selected, a final exam must be taken which is evaluated by HB Maynard personnel. Based on a score of 75% or greater, the student is certified. Recertification is required every four years.

HB Maynard personnel are available at the training centers to provide technical assistance to all clients.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
Manual Basic MOST® Tuition - Applicator	$ 925.00
Computerized Basic MOST® Tuition - Applicator	$ 925.00
Manual Basic MOST® Instructor Tuition	$1,900.00
Computerized Basic MOST® Instructor Tuition (includes manual MOST® Instructor Tuition)	$4,500.00
Annual Lease for Manual Basic MOST® Instructor	$2,400.00 First Year
	$1,500.00 Renewal
	$ 230.00/Student Kit
Software for Personal Computer or Microcomputer	$12,000
Software for Minicomputer	$60,000
Software for Mainframe Computer	$100,000

NOTES: (1) All software prices listed are for basic software only.

(2) Additional costs for implementation, which includes training and guided application, are determined on a per-client basis.

(3) A software maintenance program is available for a monthly fee of 1.25% of the original software price. This program, which provides for future software enhancements and updates, includes a 24-hour hotline service for engineering/software support.

COMPLIANCE WITH MIL STD 1567A:

The Basic MOST® predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on a review of statistical backup data provided by the vendor, the system accuracy was such that theoretically the system will generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.

- Documentation of an operations analysis.

- A record of standard practice or method followed when the standard was developed.

- A record of rating or leveling.

- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the BASIC MOST® predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- Easy to learn.
- Fast application time.
- Sequence model provides a good methods-analysis tool. Time is a function of method.
- Easy to identify time/cost reductions.
- Standards are traceable to the method.
- Not applicable to very short-cycle, highly repetitive operations.
- No specific factors for weight considerations although method of application can be adjusted.
- Computerized, key words used do not always match the shop-floor language.

SYSTEM USERS:

Based on information provided by the vendor, manual Basic MOST® is currently being utilized by approximately 6,000 companies, with more than 100 companies using the computerized version, in a variety of industries including:

- Aerospace
- Electronics
- Metal Fabrication & Removal
- Textiles
- Furniture
- Forging/Casting
- General Assembly
- Farm and Construction Equipment
- Warehouse
- Automotive
- Defense
- Food Processing
- Foundries
- Shipbuilding
- Utilities
- Finance
- Medical

REFERENCE SOURCE:

HB Maynard & Company, Inc.

MINI MOST® SYSTEMS

CONTACT: Kjell B. Zandin, Senior Vice President
COMPANY: HB Maynard & Co., Inc.
ADDRESS: 235 Alpha Drive, Pittsburgh, PA 15238
PHONE: (412) 963-8100

SYSTEM HISTORY:

See BASIC MOST® for detailed history explanation.

SYSTEM DESCRIPTION:

Mini MOST® (Maynard Operation Sequence Technique) is one member of the MOST® family of predetermined time systems whose basis is to concentrate on the displacement of objects under the premise that units of work are organized for the purpose of accomplishing some useful result through the movement of objects. Mini MOST was specifically designed to measure **identical, short-cycle operations** to be applied either manually or with the use of a computer.

The **primary work units** are **fundamental activities** (collections of basic motions) dealing with the movement of objects. Each of these activities is described in terms of subactivities fixed in a **sequence.** Consequently, the basic pattern of an object's movement is described by two **universal sequence models** instead of random, detailed basic motions.

The system ascertains that objects are moved in only one of two ways, resulting in a different sequence of events; therefore, two separate MOST® activity sequence models apply.

The Mini MOST® technique is comprised of the following two basic sequence models:

- **General Move Sequence**
- **Controlled Move Sequence**

The sequence models, in addition to describing the motions employed, provide the total time value for the activities by using index numbers. The index numbers are placed after each subactivity in the sequence and represent the time allowed for that subactivity. The tables shown on the Mini MOST® data card serve as a reference for identifying the appropriate index values.

In Mini MOST®, different motion combinations have different degrees of difficulty for simultaneous performance. Therefore in addition to the two basic sequence models, the Mini MOST® data card has a **"Simultaneous Motion Guide"** on the back to assist the user in making decisions on whether simultaneous motions should take place. The three control levels listed on this card refer to the mental and visual control the operator must exercise to complete the activity.

Mini MOST® is based on only one aspect of the work spectrum, **"identical, short-cycle operations,"** which means the method is repeated exactly, is highly repetitive, occurs no less than 1,500 times per week, and requires .25 minutes or less per cycle.

Mini MOST® is an approach based on simple construction and the grouping together of basic motions that frequently occur in sequence. In addition, the system requires the identification of only seven subactivities, with sequence models preprinted on the analysis form, requiring the analyst only to fill in the variable index numbers.

As a computerized system, it offers the advantage of being consistent in application through the use of key words to describe methods. The work-area data and key words signal the computer as to which sequence model should be used and which values should be applied, thereby eliminating errors in calculations. Also, the computer system provides the ability to edit any data, work-area information, or standards that have been previously input or calculated. In addition, this provides the engineer the ability to simulate potential improvements based on methods or work-area changes.

SYSTEM APPLICATION:

Mini MOST® has the capability to be applied either manually or in a computerized form. Although the same basic principles apply, the method of application varies as follows:

° **MANUAL:**

To apply the Mini MOST® system, the applicator must first observe and document the work area and operation method. If visualized, the method must be verified by actual shop floor observation. Once the method has been documented, the appropriate sequence model is selected as follows:

- General Move
- Controlled Move

Once selected, variations in subactivities are indicated by differences in the index value selected from the appropriate data card shown in the following example:

$$A_{16} \quad B_0 \quad G_{16} \quad A_{16} \quad B_0 \quad P_{24} \quad A_0$$

A_{16} - Reach
B_0 - No bend
G_{16} - Grasp one object with one hand
A_{16} - Move object to location for placement
B_0 - No bend
P_{24} - Place and adjust object
A_0 - No return move

The above example represents a work activity which indicates reaching for a part and positioning it to a fixture.

The time value for the sequence is obtained by adding together the index numbers. The standard time for the example sequence:

$$A_{16} \quad B_0 \quad G_{16} \quad A_{16} \quad B_0 \quad P_{24} \quad A_0 = 72 \text{ TMUs}$$

(NOTE: 1 TMU (Time Measurement Unit) equals .00001 hours. In this example, the activity required approximately 2.6 seconds to complete).

Based on studies performed by the vendor, as a general rule, one hour of work can be measured with an average of 25 hours of analyst time, once the method has been defined.

- **COMPUTER:**

To perform a Mini MOST® analysis using the computerized system, the analyst gathers workplace information and keys the information into the computer data base. Critical workplace information to be input is: 1) workplace names, locations and sizes; 2) tools and their locations; 3) objects and their locations; 4) equipment and its location, along with appropriate process times; 5) operator starting location and body motions associated with particular workplaces.

The activity being studied is documented in sentence format, starting with a "key word" that designates to the computer the sequence model to be used, as well as the values for selected sequence parameters. Key words and method descriptions conform to basic English sentence structure and engineering terminology. Utilizing the key words and the work-area data, the computer calculates the standard time for the activity being studied.

It is the vendor's belief that the Mini MOST® computer system is up to 25% faster than the manual application of Mini MOST®.

Hardware requirements for the Mini MOST® computer systems vary, depending on the user's needs. Software is available for personal computers, the IBM XT, AT or compatible microcomputers, and for Digital Equipment Corporation's minicomputer systems (VAX). An IBM mainframe version is under development.

Mini MOST®, both manual and computerized, has been designed for use by companies specializing in the assembly of small components or other activities involving short-cycle identical motions such as small appliances, some apparel and textile operations, assembly of timing devices and fusing, and other similar short-cycle tasks. Its use is intended only for **highly repetitive, short-cycle** operations with **no variations.**

TRAINING/TECHNICAL ASSISTANCE:

To use the manual Mini MOST® system, the analyst can be certified in Mini MOST® by completing a 32-hour training course which can be accomplished through a variety of training alternatives:

- ° A 32-hour lecture or self-paced course at one of HB Maynard's two training facilities.
- ° A 32-hour lecture course taught by HB Maynard personnel at the client's facility.
- ° A 32-hour lecture course taught by a licensed client instructor.
- ° A self-paced program with guidance from a licensed client instructor.

To become certified in the Mini MOST® computer system, the analyst must first be certified in manual Mini MOST® and then certified in computerized Mini MOST® by completing a 20-hour training course available through the same variety of training alternatives listed above, except that all computer-system training is lecture-style.

Regardless of the training method selected, a formal exam must be taken which is evaluated by HB Maynard personnel. Based on a score of 75% or greater, the student is certified. Recertification is required every four years.

HB Maynard personnel are available at the training centers to provide technical assistance to all clients.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
Manual Mini MOST® Tuition - Applicator	$ 725
Computerized Mini MOST® Tuition - Applicator	$ 550
Manual Mini MOST® Instructor Tuition	$1,500
Computerized Mini MOST® Instructor Tuition (includes Manual Mini MOST® Instructor Tuition)	$2,700
Annual Lease for Manual Mini MOST® Instructor	$1,800 First year
	$1,200 Renewal
	$ 155/Student Kit
Software for Personal Computer or Microcomputer	$13,200
Software for Minicomputers	$66,000
Software for Mainframe Computer	$110,000

NOTES: (1) All software prices listed are for basic software only.

(2) Additional costs for implementation, which includes training and guided application, are determined on a per-client basis.

(3) A software maintenance program is available for a monthly fee of 1.25% of the original software price. This program, which provides for future software enhancements and updates, includes a 24-hour hotline service for engineering/software support.

(4) Software costs include the Basic MOST software package of which Mini MOST is a supporting module.

COMPLIANCE WITH MIL STD 1567A:

The Mini MOST® predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.

- Documentation of an operations analysis.

- A record of standard practice or method followed when the standard was developed.

- A record of rating or leveling.

- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the Mini MOST® predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- Avoid rating problems of time study.
- Can set standards prior to operation.
- Fast application time.
- Easy to learn.
- Standards maintenance easy with computer.
- Easy to switch from Basic to Mini.
- Application is consistent.
- System is accurate.
- Can't analyze wrist movement (90° angles) or muscle movement.
- Very minute motions sometimes cannot be accounted for.
- May have trouble applying to extremely short cycles (two to three seconds).

SYSTEM USERS:

No specific user data was provided by the vendor. Approximately 1500 individuals have been trained in the application of the Mini MOST® system.

REFERENCE SOURCE:

HB Maynard and Company, Inc.

MAXI MOST® SYSTEMS

CONTACT: Kjell B. Zandin, Senior Vice President
COMPANY: HB Maynard & Co., Inc.
ADDRESS: 235 Alpha Drive, Pittsburgh, PA 15238
PHONE: (412) 963-8100

SYSTEM HISTORY:

See BASIC MOST® for detailed history explanation.

SYSTEM DESCRIPTION:

Maxi MOST® (Maynard Operation Sequence Technique) is one member of the MOST® family of predetermined time systems whose basis is to concentrate on the displacement of objects under the premise that units of work are organized for the purpose of accomplishing some useful result by simply moving objects and operating tools or equipment. Maxi MOST® was specifically designed to measure **nonidentical, long-cycle, heavy assembly or machining operations** and can be applied either manually or with the use of a computer.

The **primary work units** are **fundamental activities** (collections of basic motions) dealing with the movement of objects as well as operating tools, equipment and machines. Each of these activities is described in terms of subactivities fixed in a **sequence.** Consequently, the basic pattern of an object's movement is described by **universal sequence models** instead of random, detailed basic motions.

Maxi MOST® requires the use of five special sequence models for analyzing long-cycle operations. The five sequence models are as follows:

- **ABP - Parts Handling**
- **ABT - Tool/Equipment Use**
- **ABM - Machine Handling**
- **ATKTPTA - Transport with Powered Crane**
- **ASTLTLTA - Transport with Wheeled Truck**

Each of the parameters represents a particular action and/or tool/equipment use.

The sequence models, in addition to describing the motions employed, provide the total time value for the activities by using index numbers. The index numbers are placed after each subactivity in the sequence and represent the time allowed for that subactivity. The tables shown on the Maxi MOST® data cards serve as a reference for identifying the appropriate index values.

Maxi MOST® was designed to provide an efficient work measurement system to be used to analyze large-scale work where a more precise system might be too detailed and cumbersome. Each analysis requires the identification of only three subactivities for the basic sequence models, and seven subactivities for the powered crane and truck sequence models.

Maxi MOST® differs from Basic MOST® because it concentrates on one aspect of the work spectrum: **nonidentical, long-cycle operations.** It is best-suited for operations having **low unit-production rates and long unit-production times.**

The system vendor states it is best suited for cycles of two minutes or longer.

SYSTEM APPLICATION:

Maxi MOST® can be applied either manually or in a computerized form. Although the same basic principles apply, the method of application varies as follows:

- **MANUAL:**

  To apply the Maxi MOST® system, the applicator must first observe and document the operation method. If visualized, the method must be verified by actual shop floor observation. Once the method has been documented, the appropriate sequence model is selected as follows:

  - ABP - Parts Handling
  - ABT - Tool/Equipment Use
  - ABM - Machine Handling

- ATKTPTA - Transport with Powered Crane
- ASTLTLTA - Transport with Wheeled Truck

Once selected, variations in subactivities are indicated by differences in the index value selected from the data card as follows:

$A_3\ B_0\ P_1$

A_3 - One or several action distances included in activity
B_0 - No body motion
P_1 - Placement or placements

The above example represents an activity which indicates the placing of a subassembly to an assembly 12 steps away and requiring no body motion.

The time value for the sequence is obtained by adding together the index numbers and multiplying the sum by 100. The standard time for the example sequence:

$A_3\ B_0\ P_1 = 4 \times 100 = 400$ TMUs

(Note: 1 TMU (Time Measurement Unit) equals .00001 hrs.; therefore, 400 TMUs equals .0040 hrs. or 14.4 seconds).

Based on studies performed by the vendor, as a general rule, one hour of work could be measured with an average of two to five hours of analyst time, once the method has been defined.

° **COMPUTER**:

To perform a Maxi MOST® analysis using the computerized system, the analyst gathers work-area information and keys the information into the computer data base. Critical work-area information to be input into the computer is: (1) workplace names, locations and sizes; (2) tools and their locations; (3) objects and their locations; (4) equipment and its location, along with appropriate process times; (5) operator(s) and starting location(s) and body motions associated with particular workplaces and the distance (in steps) between workplaces.

The activity being studied is documented in sentence format, starting with a "key word" that designates to the computer the sequence model to be used, as well as the values for selected sequence parameters. Key words and method descriptions conform to basic English sentence structure and engineering terminology. Utilizing the key words and the workplace data, the computer calculates the standard time for the activity being studied.

Major advantages of the computer system are: the consistency offered by the key word approach to method descriptions, calculation errors and errors from selecting wrong values from the charts are eradicated, and the ability to edit any data, work-area information or standards that have previously been input or calculated.

It is the vendor's belief that the Maxi MOST® computer system is up to 25% faster than manual Maxi MOST®.

Hardware requirements for the Maxi MOST® computer systems vary depending on the user's needs. Software is available for personal computers, the IBM XT, AT or compatible microcomputers, and for Digital Equipment Corporation's minicomputer systems (VAX). An IBM mainframe version is under development.

Maxi MOST®, both manual and computerized, has been designed to be used by companies whose operations include nonidentical, non-repetitive long-cycle tasks in industries such as shipyards, railcar fabrication, steel-rolling mill fabrication and assembly, missile-system production, and chemical-process operations. Its use is intended only for **non-repetitive, long-cycle operations with variations.**

TRAINING/TECHNICAL ASSISTANCE:

To use manual Maxi MOST®, the analyst must first be certified in the use of Basic MOST®. To become certified, a 32-hour training course is required (in addition to the 40-hour Basic MOST® course) which can be achieved through a variety of alternatives as follows:

- A 32-hour lecture or self-paced course at one of HB Maynard's two training facilities.

- A 32-hour lecture course taught by HB Maynard personnel at the client's facility.

- A 32-hour lecture course taught by a licensed client instructor.

- A self-paced program with guidance from a licensed client instructor.

To become certified in the Maxi MOST® computer system, the analyst must first be certified in manual Maxi MOST® and then can be certified in computerized Maxi MOST® by completing a 20-hour training course available through the same variety of training alternatives listed above except all computer-system training is lecture-style.

Regardless of the training method selected, a final exam must be taken which is evaluated by HB Maynard personnel. Based on a score of 75% or greater, the student is certified. Recertification is required every four years.

HB Maynard personnel are available at the training centers to provide technical assistance to all clients.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
Manual Maxi MOST® Tuition - Applicator	$ 775
Computerized Maxi MOST® Tuition - Applicator	$ 550
Manual Maxi MOST® Instructor Tuition	$1,750
Computerized Maxi MOST® Instructor Tuition (includes Manual Maxi MOST® Instructor Tuition)	$2,700
Annual Lease for Manual Maxi MOST Instructor	$2,400 First Yr.
	$1,500 Renewal
	$ 240/Student Kit
Software for Personal Computer or Microcomputer	$13,200
Software for Minicomputer	$66,000
Software for Mainframe Computer	$110,000

NOTES: (1) All software prices listed are for basic software only.

(2) Additional costs for implementation, which includes training and guided application, are determined on a per-client basis.

(3) A software maintenance program is available for a monthly fee of 1.25% of the original software price. This program, which provides for future software enhancements and updates, includes a 24-hour hotline service for engineering and software support.

(4) The software prices include the Basic MOST® software package of which Maxi MOST® is a supporting module.

COMPLIANCE WITH MIL STD 1567A:

The Maxi MOST® predetermined time system is in compliance with the specific requirements set forth in MIL.STD.1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.

- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.
- A record of observed or predetermined time system time values used in determining the final standard time.
- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the Maxi MOST® predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- System is accurate.
- Fast application time.
- Application is consistent.
- Easy to use and understand.
- Allows for slight variations in methods inherent in long-cycle jobs.
- No specific data for surface preparation (i.e., sanding, washing).

SYSTEM USERS:

No specific user data was provided by the vendor. Approximately 800 individuals have been trained in the application of the Maxi-MOST® system.

REFERENCE SOURCE:

HB Maynard & Company, Inc.

CUE/DART

TECHNICAL CONTACT: Douglas M. Towne, PH.D., Vice-President
COMPANY: General Analysis, Inc.
ADDRESS: P.O. Box 7000-421, Redondo Beach, CA 90277
PHONE: (213) 540-3629

MARKETING CONTACT: Jack Hansen
COMPANY: HJ Hansen Company
ADDRESS: 545 West Golf Road, Arlington Heights, IL 60005
PHONE: (312) 439-7979

SYSTEM HISTORY:

CUE was developed in 1977-78 by Douglas M. Towne, Ph.D., of General Analysis, Inc. CUE was developed specifically to be applied by automated means in order to achieve maximum simplicity of user codes. Installations in the late 1970s involved the use of programmable calculators which could be loaded with the CUE formulas.

DART, the computer program which applies CUE, as well as the other modules described was developed by General Analysis in the early 1980s. DART was developed for use on a personal computer to take advantage of the ease and speed of processing provided by the computer.

SYSTEM DESCRIPTION:

CUE is a computerized, predetermined time measurement system derived from having analyzed MTM-1 data and motion-time tables. CUE was developed specifically for application by computer or programmable calculator.

DART, to be used in conjunction with CUE, is an automated work measurement system which generates and maintains labor standards. DART is a basic "core" program which can interface with a number of optional CUE/DART modules as well as with data developed by using other predetermined time systems or the user's own standard data. This enables the analyst to build a work measurement system tailored for their particular needs. Each module is presented on the following pages:

- **DART CORE**

  Represents the basic standards development and maintenance program, and includes standards buildup, save and retrieve, formula application, where-used listing, mass update, application of "operation sheets," and selective index listings. The CORE program has the capability to apply a user's own standard data and/or the CUE motion-analysis system, described below.

- **DART CUE**

  Represents the motion-level analysis system for documenting and quantifying work methods. The system includes both a one-hand and a two-hand mode of analysis; the two-hand mode also provides detailed analyses of idle time and hand-loading. CUE applies predetermined times to basic manual motions such as Get, Move, Position, Walk, Crank, and Turn.

  Variables for distance, weight, and precision are specified as required by each motion type. The DART CUE module may be used independent of the DART CORE module by using a TI Programmable Calculator; however, the system vendor recommends that the DART CUE module be used in conjunction with the DART CORE module on a personal computer.

- **DART RAM I**

  RAM I is a combination of preconstructed machining-process time formulas with a variable-prompting routine. This routine, built into DART, requests from the applicator all necessary information about the machining operations, and enters the information into the DART analysis. The DART RAM I module must be used in conjunction with the DART CORE module.

- **DART RAM II**

  RAM II is a stand-alone program which computes optimum machine speeds to minimize cutting time and cutting cost for a specified machining operation. The DART RAM II module must be used in conjunction with the DART CORE module.

- **Preconstructed Standards Data:**
  In addition to the above modules, the system also has the following data banks which contain pre-analyzed elements recognized by DART and ready for use in standards buildup:

  - **Machine Tool: manual machine-shop elements**
  - **Light Assembly: manual assembly elements**
  - **Printed Circuit Board Assembly**
  - **Wire Harness Fabrication**

SYSTEM APPLICATION:

CUE is a data base of predetermined time elements which are input into the DART CORE program to develop labor standards for manual activities. All manual work is described to DART/CUE in terms of element codes. These codes signify what work is accomplished.

The table below summarizes the basic CUE elements available for standards application.

G - Get
M - Move
P - Position
D - Disengage
C - Crank
F - Finger Motion
H - Horizontal Body Motion (walk, side step, turn)
V - Vertical Body Motion (bend, sit, stand, arise)
E - Eye Action (focus or eye travel)
AP - Apply Pressure
FM - Foot Motion
PT - Process Time

In addition to the above elements, user-defined standard data can be used to supplement the basic elements.

Each basic work element is preceded by some numerical value representing distance, diameter, weight, etc. For example, the variables associated with a MOVE are distance and weight, thus the CUE input code for MOVE 20-pound box to bench with two hands, 18 inches, is: 18.10M. The value entered for weight is the amount of weight overcome by one arm, expressed as a two-digit number. An example operation analyzed by DART CUE is shown below:

- STAMP NUMBER ON LABEL.

LINE	DESCRIPTION	ELEMENT	TIME	FREQ	TOTAL
	Get Stamp	12.1G	16	1	16
	Get Regrasp Stamp	.1G	7	1	7
	Move Stamp to Pad	12M	13	1	13
	Apply Pressure	AP	15	1	15
	Move Stamp	6M	9	1	9
	Get Regrasp Stamp	.1G	7	1	7
	Move to Part	12M	13	1	13
	Position to Part	4P	20	1	20
	Eye Check	2E	20	1	20
	Apply Pressure Stamp	AP	15	1	15
	Move Aside Stamp	12M	13	1	13
	Eye Visual Imprint	2E	20	1	20

STND. HRS/THOU.	1.93
MACH. ALLOWANCE	0.20
MANUAL TIME (IN TMU)	168.00
MACHINE TIME	0.00
TOTAL MINUTES	0.10
TOTAL HOURS	0.00

CUE allows for metric conversions of the values associated with each of the basic work elements input into the DART CORE program during the development of labor standards.

The system can be used for both **short-cycle and long-cycle work** activities. Generally, standard data elements built from CUE basic-motion codes are used for longer-cycle work. Although CUE is best suited for **highly repetitive activities**, with **no variations**, the system vendor states that the CUE system can be used effectively in relatively variable environments because of its speed in application. In addition, the system allows users to analyze several variations of work content, and then calculate a weighted average to reflect the average time required.

As previously stated, the CUE system was developed specifically for application by computer or programmable calculator and can be used in conjunction with:

- TI programmable calculators
- Apple II series computers
- Apple III computers
- IBM PC/XT/AT series computers
- All IBM-compatible computers (i.e., Compaq, Zenith, and Xerox)

TRAINING/TECHNICAL ASSISTANCE:

General Analysis provides five days of basic system training, which includes three days of classroom instruction and two days for guided application in the user's plant. General Analysis recommends an additional two weeks of training in which to cover standard data development and other general work-measurement application topics. All training is conducted at the client's site and a certification examination is administered upon completion of the training course.

Although retraining is available, it has rarely been requested. It is the vendor's belief that it is common practice for users, once trained by General Analysis instructors, to perform periodic in-house training for additional users of the CUE system.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE (1)
Module: DART Core	$19,000 (2)
Module: DART CUE	$ 5,000
Module: DART RAM I Machine Shop	$ 2,500
Module: DART RAM II	$ 1,500
Pre-Constructed Standards Data:	
- Machine Tool: Manual Machine-Shop Elements	$5,000
- Light Assembly: Manual Assembly Elements	$6,000
- Printed Circuit Board Assembly	$4,500
- Wire Harness Fabrication	$3,000
Two weeks of additional on-site training and system implementation assistance	$5,200

NOTES: (1) A **65% discount** is applied on modules ordered collectively for additional sites.

(2) The price for DART CORE includes three days of on-site training time, plus three DART user's manuals. In addition an extended software update service, which provides all enhancements developed during the next 12 months, is also included.

COMPLIANCE WITH MIL STD 1567A:

The CUE/DART predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.

- Documentation of an operations analysis.

- A record of standard practice or method followed when the standard was developed.

- A record of rating or leveling.

- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the CUE/DART predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- Easy to apply.

- Computerized application provides improved speed, accuracy, and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" method-improvement scenarios.

- System will accept and manipulate data developed by utilizing other work measurement systems or techniques.

- Mass updating using the computerized version requires substantial time and effort to code each level of data so as to provide a link of traceability when mass updating.

- System users have experienced slow response from the system vendor.

SYSTEM USERS:

Based on data supplied by the system vendor, a breakdown of system users by manufacturing type is as follows:

APPLICATION TYPE	NUMBER OF COMPANIES
Electronics	11
Machined Parts	7
Precision Instruments	4
Farm, Industrial & Automobile	4
Commercial Appliances, Tools	3
Cosmetics	1
Toys	1
Plastics	1

REFERENCE SOURCE:

General Analysis, Inc.

MASTER STANDARD DATA (MSD)

CONTACT: Harold W. Nance, President
COMPANY: Serge A. Birn Company, Division of SABCO, Inc.
ADDRESS: 5328 Wooster Road, Cincinnati, OH 45226
PHONE: (502) 451-6640

HISTORY OF SYSTEM:

The development of **Master Standard Data (MSD)** was initiated in the late 1950s by analyzing thousands of MTM-1 analyses of individual operations as well as those used for standard data. Based on these analyses, it was found that certain basic MTM-1 motion combinations were continually repeated. The basic MSD card was completed in 1960 and a textbook published in 1962.

The MSD system was developed by the late Richard M. Crossan and Harold W. Nance of the Serge A. Birn Company. Client facilities were used to test and validate the resulting data.

SYSTEM DESCRIPTION:

MSD is a catalog of fifty-four elements associated with time values based on combinations of the most commonly used Methods Time Measurement (MTM-1) motions.

MSD was developed from the concept that there are only two ways of getting something and only three places to put it. To get something, it is easy (some control), or difficult (high control), and it is put in the other hand, in a general location, or in an exact location.

In addition, MSD is based on four primary concepts, as follows:

- **"Horizontal" Data** - Time data, or standard data, are developed by type of activity regardless of where or for what purpose it is performed as opposed to developing the standard data by department.

- **"Building Block Concept"** - Where the "size" of the blocks (number of combined time elements) is increased in proportion to the duration of the work.

- **"Alpha Mnemonic"** - Involves coding for time elements where letters are used to clearly identify the activities at hand, and to serve as a memorization technique for identification purposes as illustrated in the following examples:

  - **MISD** = **M**ulti-Purpose **I**nspect with **S**cale-**D**epth
  - **MJSP** = **M**ulti-Purpose **J**ob Preparation **S**tudy **P**rint.

- **Rate Calculation Sheets** - All time values for a given job or machine are preprinted on a form, allowing the analyst setting a standard to check off the relevant elements and their frequencies on the form. These values are then extended to develop the standard.

SYSTEM APPLICATION:

MSD has the capability to be applied either manually or in computerized form. Both are based on the same basic principles and application method.

In developing a standard using MSD, after observing the operation, the analyst applies the proper MSD element code obtained from one of the six tables on the MSD data card. With the manual method, the analyst copies the code and the time value from the data card. Whereas, with the computerized method, the analyst inputs the code and the computer locates the correct time value. If the operation is visualized, rather than observed, the method must be verified by actual shop floor observation. An example MSD analysis is shown below:

STEP 2 - PLACE CASTING IN AND ALIGN FIXTURE

LN	DESCRIPTION	CODE	FREQUENCY	TIME
1	Obtain casting and place in	O6H1	1.0000	21.00
2	Fixture.	P6L1	1.0000	16.00
3	Close fixture and secure part	P6G	1.0000	9.00
4	In fixture.	EF	1.0000	11.00
5	Position fixture for drilling holes	P2G	2.0000	10.00

Average time per item 67.00 Total Time 67.00

All time values are in time measurement units (TMUs). Once the operation time has been calculated, the analyst may add any necessary fatigue/delay allowances to develop the final standard.

The computerized version of MSD, called **MOD-II**, provides additional features to the development of standards. It allows for the development and storage of standard data and for the maintenance (update/delete) of any level of data. The computer also provides a mass update function which allows any element or operation changes to be made universally.

During its application, MSD encourages the use of a "Building Block" approach to develop standard data and is horizontal rather than the conventional vertical structure. The first step consists of combining MSD elements into work elements, which are applicable to most operations performed in a company, and are called **"Multi-Purpose Elements"**. The next step is to combine the Multi-Purpose Elements and MSD elements into elements that apply to a given category of work, such as Punch Presses, Shears, and Press Brakes. This combination is called "**Limited Purpose Elements**" and contains elements that are common to only that particular group of equipment. Finally, these levels are combined into **"Single Purpose Elements"** which apply to a specific kind of operation, such as Punch Presses. When analyzing an operation, the appropriate elements are placed on a rate calculation sheet to be used in establishing operation standards, either manually or computerized.

The MSD system has been applied to sheet metal fabrication, metal working, assembly, mechanical, and electrical/electronic operations. In addition, special applications of MSD are used for maintenance work and shipping and receiving.

The MSD system can be applied to both **short** or **long cycle** jobs provided the short cycle job does not have overlapping motions. If overlapping motions do exist, then a special version of MSD must be utilized. MSD can be applied to both **highly repetitive**, or **non-repetitive** jobs **with** or **without variations** in method, provided the proper approach is taken in its application. For a

highly repetitive operation, MSD would be used to measure the best method for performing the required work. For non-repetitive work, MSD would be used to measure the probable method by which the work would be performed.

The computer system, **MOD-II**, has been designed for use on an IBM XT or AT or compatible hardware, and can be used to mass update standards as well as develop standard data. In addition, MSD offers a performance reporting software package, **MOD-III**, that integrates with MOD-II to create labor distribution reports.

The system vendor states that utilizing the above concepts can reduce the time required to set standards by 60 to 80% (exclusive of methods work) when compared to more conventional means (i.e., time study).

TRAINING/TECHNICAL ASSISTANCE:

The MSD Training Course requires one week (40 hours) and, upon completion, each trainee must take a final examination and is certified based on a score of 80% or better.

The MSD Training Course is presented in a variety of ways, as follows:

- A 40-hour lecture course and examination conducted by an MSD-trained instructor at the client's facilities.

- A 40-hour self-paced course and examination monitored by an MSD-trained instructor at the Serge A. Birn Company Training Center.

- Leasing the MSD Self-Paced Training Course and having the training monitored by a certified user of MSD.

- Periodic public lecture courses presented by the Serge A. Birn Company.

All training and examination materials are supplied and graded by the system manufacturer. Outside trainers must be recertified every four years. Technical assistance is available from the system manufacturer on an as-needed basis.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
MSD Basic Training Course	$ 450
MSD Appreciation Training Course	$ 130
MOD-II Software System (1)	$12,000
MOD-III Software System - stand alone (2)	$ 5,000
MOD-III Software - with MOD-II	$ 3,000

NOTES: (1) All software prices listed are for software only. In addition, three days of consulting assistance will be supplied at the cost of living and travel expenses to assist in placing it on the computer and in training personnel in its use.

(2) This includes two days of consulting at the cost of living and travel expenses.

COMPLIANCE WITH MIL STD 1567A:

The MSD predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.

- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MSD predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- As a standard data system, it provides a substantial amount of standard data for commonly used equipment and operations.

- Past technical assistance provided by the system vendor has been exceptional.

- The system is easily applied.

- Computerized application provides improved speed, accuracy and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" methods improvement scenarios.

- Generates good documentation of the work sequence or process being analyzed.

- Standard data provided by the system vendor does not cover some unique equipment or operations.

SYSTEM USERS:

Based on data supplied by the system vendor, a breakdown of system users by manufacturing type is as follows:

APPLICATION TYPE	NUMBER OF COMPANIES
Metal Fabrication	60-80
Machining	40-50
Electrical	30-40
Assembly	120-150

REFERENCE SOURCE:

Serge A. Birn Company

NAVAIR - ELEMENTAL STANDARD DATA

CONTACT: David Hordos
COMPANY: Naval Air Rework Facility, Code 634
ADDRESS: US Naval Air Station, Alameda, CA 94501
PHONE: (415) 869-3447

SYSTEM HISTORY:

The **Elemental Standard Data (ESD) System** is a composite of Methods Time Measurement (MTM) and the Naval Aviation Logistics Center (NALC) developed data. MTM General Purpose Data (GPD) elements, which is the first-level "building block" in the development of more comprehensive standard data, have been derived from MTM analysis of repetitive motion patterns. GPD is a collection of tested data donated through the years by sustaining and professional members of the MTM Association for Standards and Research.

The higher-level standard data used by the ESD System, **Omni-purpose data** and **Specific data**, are developed on an ongoing basis at the six Naval Air Rework Facilities (NARF) and compiled by the NALC as part of that entity's Performance Standards Program. The development of the mentioned data began in the mid 1960s and Specific Data development continues today.

SYSTEM DESCRIPTION:

ESD is a predetermined time system based on MTM and is composed of two types of data: **Universal** and **Specific.** Both are coded by using a seven-position mnemonic coding system.

Universal data is composed of three levels of data: Basic-purpose, Multi-purpose, and Omni-purpose. **Basic** and **Multipurpose** data are composed of MTM General Purpose Data (GPD) and Multipurpose level elements provided by the MTM Association and supplemented with NALC-developed Multipurpose data. The third data level, **Omni-purpose** data, consists of 829 coded data elements, each describing within limits the complete accomplishment of an element of work. Omni-purpose data elements embody a three-fold concept: (1) the element work content provides for ready application to the usually observed or synthesized requirements of a job; (2) elements portray an average of acceptable shop

methods; and (3) elements provide for performance of the same, overall work content, as defined in the element title, under different levels of difficulty.

Specific data elements are defined as a combination of Basic-purpose, Multipurpose, Omni-purpose and/or other Specific data elements developed for, and applicable to, specific areas, operations or identities.

ESD is a systematic technique for developing engineered time standards using appropriate language-coded building blocks, based on MTM, and factored and compiled to provide for the best method. The table below shows the data levels previously described and their most common uses in development of standard data.

DATA LEVEL	USE: STANDARDS DEVELOPMENT	USE: DATA DEVELOPMENT
Specific	X	X
Universal		
- Omni	X	X
- GPD (Basic and Multipurpose)	X	X
- MTM		X

MTM is normally used only in the development of GPD elements. GPD is the lowest construction level of data used to provide support for NALC Elemental Standard Data.

SYSTEM APPLICATION:

The application of ESD can be more accurately defined as the application of Omni-purpose data since it is the level which is most commonly used to develop standards with this system.

The application of Omni-purpose data utilizes three questions, as follows:

° What is done?

° What element describes what is done?

° What case describes the level of difficulty or condition under which it is done?

Work content may be determined by observing the operation being performed or by synthesizing the operation content prior to production. The synthesis is obtained from technical manuals, parts, books, knowledge of shop practice, and discussions with both shop and staff people. If synthesized, the method must be verified by actual shop floor observation.

Standard data elements are developed by employing a seven-position mnemonic code. The first code group is comprised of three alphas with the first alpha designating the element level. The next two alphas designate the element category (i.e., AC - Accurate, BM - Body Motion, CL - Clean, CP - Clamp, DP - Dip).

The second code group, Code Positions 4 and 5, is composed of two alphas, with the first alpha designating the general component or process category, and the second alpha designating the specific component or process subcategory.

The third group, Code Positions 6 and 7, is composed of two alphas or an alpha and a numeric, with the first alpha designating the operation and also whether the element applies to the first or an additional piece being processed (i.e., I - Install, first piece; X - Install, additional piece; R - Remove, first piece; Y - Remove, additional piece; O - Other, first piece; Z - Other, additional piece). The second digit may be an alpha or a numeric and designates the element case. When the element is developed into a level of difficulty structure, an alpha is used (i.e., A - Very easy; B - Easy; C - Moderate; D - Difficult; E - Very Difficult). When the element is developed in a structure relating to physical limitations such as a size or condition, a numeric is used.

The development of labor standards using Omni-purpose data of the ESD system requires defining an activity's work elements in detail by using the previously discussed seven-position mnemonic code. An example of a coded activity (and explanation of each code) follows:

EXAMPLE: ONF-PC-IC

FIRST GROUP	O	1st alpha designates ELEMENT CLASSIFICATIONS, O - Omni-purpose
	NF	Next two alphas designate ELEMENT CATEGORY, NF - Non-threaded Fasteners
SECOND GROUP	P	1st alpha designates GENERAL COMPONENT, P - Pin
	C	2nd alpha designates SPECIFIC COMPONENT, C - Cotter
THIRD GROUP	I	1st alpha designates OPERATION, I - Install, 1st piece
	C	2nd alpha designates degree of DIFFICULTY, C - Moderate difficulty

Each element has a time value for Installation, Removal or Other as may apply. This value is stated for a first or additional piece, if appropriate. The first piece is defined as those motions necessary to accomplish the element, as defined in its work content, separate and apart from any other element. The additional piece is defined as only those motions necessary to accomplish the "do" portion of an element.

The system vendor states that the ESD system, at various levels, has application in a variety of production activities including, but not limited to, fabrication, assembly, modification, repair, preservation, testing, and cleaning. Omni-purpose data and Specific data have been developed and applied primarily in aircraft repair and maintenance tasks. The system vendor states that the ESD system can be applied to either **short- or long-cycle jobs**, and **highly repetitive**, with **no variations**, or **non-repetitive**, with **variations**.

Application of the ESD system can be either manual or computerized. The computerized version requires a minimum of 30 megabytes fixed-disk storage with 640K bytes of available memory to execute the ESD programs.

TRAINING/TECHNICAL ASSISTANCE:

Successful application of the ESD work measurement system requires that the analyst be trained in MTM-1 prior to being trained in the use of ESD. MTM-1 training is provided by MTM-certified instructors at the MTM Association training site, the user's facility, or at one of the six Naval Air Rework Facilities. ESD training is provided by NALC instructors at the user's facilities or at one of the six NARFs. The training course covers the methodology and application of MTM-GPD, Omni-purpose, and Specific data. The ESD course takes four weeks to complete and is followed by a certification exam.

SYSTEM COSTS:

The ESD system has been used almost exclusively within the United States government. It is for this reason that the Naval Aviation Logistics Center prefers to address system cost information on a per-request basis from interested companies.

COMPLIANCE WITH MIL STD 1567A:

Since no statistical backup data was available to verify the theoretical accuracy of the system, it was impossible to evaluate the ability of the ESD predetermined time system to comply with specific requirements set forth in Paragraph 5.1 of MIL STD 1567A for Type I Engineered Labor Standards. Those basic requirements, as specified in the MIL STD, which are in question are as follows:

- All Type I standards must reflect an accuracy of $\pm 10\%$ with a 90% or greater confidence at the operation level.

Those requirements which the system **does** meet are as follows:

- Documentation of an operations analysis.

- A record of standard practice or method followed when the standard was developed.

- A record of rating or leveling.

- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the ESD predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- As a standard data system, it provides a substantial amount of data primarily related to repair and maintenance activities of aircraft, avionic and ground-support equipment, thereby reducing standards development efforts.

- The system has various levels of data that can be used to develop standard data for activities not covered by the higher-level standard data.

- The Department of Defense requires an extremely comprehensive training and certification program prior to using the system.

- The standard data contained in the system has not been periodically reviewed to ensure accuracy and consistency of the backup data.

- Optimal use of the system requires a knowledge of the repair and maintenance activities of aircraft, avionic and ground-support equipment.

SYSTEM USERS:

The ESD system has been used extensively by defense-related contractors in a variety of work areas. Specific data has been developed and used primarily by the Naval Air Rework Facilities in aircraft and avionic equipment repair and maintenance activities.

REFERENCE SOURCE:

Naval Air Rework Facility

WORK-FACTOR®

CONTACT: James S. McGurk, V. P., Operations
COMPANY: Science Management Corporation
ADDRESS: P.O. BOX 0600, 140 Allen Road, Liberty Corners, Basking Ridge, NJ 07938
PHONE: (201) 647-7000

SYSTEM HISTORY:

Work-Factor® research was initiated in 1934 in a large manufacturing corporation by a group of industrial engineers whose objective it was to develop a system which would remove the element of human judgment which existed in stopwatch time study, and caused much labor-management strife.

The Work-Factor® Time Values were developed from thousands of observations taken in the shop and checked in the laboratory over a period of several years. These observations involved the use of special stopwatches, micromotion analysis of films, stroboscopic-camera measurements, and the use of special photoelectric timing devices. The research was conducted in factories and offices, using actual workers performing actual operations under prevailing working conditions.

Having spent a year checking, correcting, and simplifying the System, it was placed in general use in 1938. Over the next several years, it was recognized that less stringent analysis was appropriate in different situations (i.e., mass production, medium-quantity production, and small-quantity production.) To accommodate this, second and third levels of Work-Factor® were developed. These are called Ready Work-Factor®, and Brief Work-Factor®.

In addition, a computer application program, WOCOM II, has been developed to enhance the Work-Factor® methods. The System may be set up to utilize either the Detailed, Ready, or Brief Work-Factor® tables or it may utilize any combination of these methods simultaneously.

SYSTEM DESCRIPTION:

Work-Factor® is based on a concept of having a catalog of manual motion and mental-process times arranged in such a manner that an appropriate time can be obtained for every manually controlled motion likely to be encountered in any work situation. In the Work-Factor® System this catalog is known as the **Motion Time Table**, and is used according to specific rules and procedures.

Work-Factor® Times may be used for analyzing and establishing standards for specific operations. They may also be used to establish formulas or standard data which can be applied to many operations in the same family of work.

Flexibility has been achieved by developing different procedures of application depending on the accuracy required. The procedures are known respectively as the **Detailed, Ready**, and **Brief Work-Factor®** techniques.

Because the three techniques have been compiled from the same basic data, they are fully integrated and function as a system. In addition, the computer application program incorporates any or all of the Work-Factor® techniques.

° **Detailed Work-Factor®**: is used when **high accuracy** and **consistency** are required and when the cost of precise time standards is exceeded by the cost savings resulting from their accuracy. The system has been developed based on the premise that all work is made up of motions which Work-Factor® has combined into subdivisions called **standard elements.** Work-Factor® has identified eight standard elements which are each described below.

STANDARD ELEMENT	SYMBOL
Transport - Relocate a body member (Reach) or an object (Move).	R,M
Grasp - Obtain control of an object.	Gr
Release - Let go of an object.	Rl
Pre-position - Reposition an object.	PP
Assemble - Mate two objects.	Asy

STANDARD ELEMENT	SYMBOL
Use - Utilize tools and machines.	Use
Disassemble - Take things apart.	Dsy
Mental Process - Use the senses and brain.	MP

In addition to the Standard Elements described above, there are some motions which require special analytical procedures. These motions include writing and printing, walking, body turns, circular motions, using tweezers and microscopes, and repetitive motion patterns.

The Detailed Work-Factor® Motion Time Table has been arranged to cover all types of manual motions performed in any form of operation. Therefore, in addition to the Standard Elements, there are four **Major Variables** which influence the time to make an individual motion as follows:

- **Body Member**: Determined by observation, the system recognizes a difference in the speed with which the various body members move when performing work (i.e., Finger, Arm, Forearm swivel, Trunk, Leg, Foot).

- **Distance Moved**: Can be measured with a scale or rule.

- **Weight carried or resistance encountered**: Consideration is given to this variable by means of Weight Limits.

- **Motion difficulty**: The most complex, it may be observed and is a function of the purpose of the motion. Some motions are more difficult than others. Variables in motions are as follows:

    - Basic Motion: A motion which involves little or no difficulty, or precision (i.e., tossing an object, waving the arm, or dropping the hand to the side of the body).

°° Work-Factor®: An index of difficulty, which designates the degree of difficulty contained in any motion, as follows:

W- WEIGHT OR RESISTANCE - represents the additional difficulty present in a motion due to the retarding effect of weight, or the force required to overcome resistance within the limits specified in the Motion Time Table.

S- STEER, Directional Control - represents the manual control required to perform a motion directed toward a small target area.

P- PRECAUTION - represents the manual control required to perform a motion when it is necessary to exercise caution to prevent damage or injury or to maintain control.

U- CHANGE OF DIRECTION - represents the manual control required to move around a curved motion path.

D- DEFINITE STOP - is the manual control required to terminate a motion at a specified location at the will of the operator.

The various kinds of Motion Difficulty (Control) recognized in the Work-Factor® System are remembered by memorizing the symbols representing the difficulties, W-SPUD. A motion can include up to four degrees of difficulty due to Weight but only one of the other difficulties.

The effect on Motion Time of each of the difficulties is the same. That is, if all other factors are the same, a motion involving only Precaution requires the same time as one involving only Definite Stop; a motion involving one Weight Difficulty plus Change of Direction requires the same time as one involving Steer and Definite Stop and so on.

- **Ready Work-Factor®**: is an extension of the Detailed Work-Factor® system. Its purpose is to provide greater flexibility, speed, and wider application to the basic Detailed Work-Factor® technique.

The same standard elements as used in Detailed Work-Factor® are also used in Ready Work-Factor®. The **Major Variables** identified in Detailed are the same in Ready. Two of the variables, while using the same rules as in Detailed, are expressed differently as follows:

- **Motion Distance:** It should be noticed that the Ready Work-Factor® system describes distances two ways--with words and in inches. A "very short" motion is any distance up to four inches. A "short" motion ranges anywhere from over four inches up to and including 10 inches, etc.

- **Motion Difficulty:** is described in the same fashion--in words and in terms of Work-Factors®. A "Very Easy" motion is a basic motion with no Work-Factors®, an "Easy" motion has one Work-Factor®, an "Average" motion has two Work-Factors®, etc.

Through simple graphic terminology and a minimum number of time values, the Ready Work-Factor® System creates a work-time association in the minds of its users. Time values become thoughts, easily applied mentally and conversationally.

Used in conjunction with a few simple rules and guideposts, these time values are suitable for establishing time standards in almost all applications, including measured day work and incentive operations.

° **Brief Work-Factor®**: also based on Detailed Work-Factor®, has been designed to measure non-repetitive work and provide accuracy with a minimum of analytical effort and time.

Brief Work-Factor® Time Values are provided for all human work except that controlled by machines or processes the same as in Detailed and Ready. There are four simple tables covering the Work-Segments: (1) Pick-up, (2) Assemble, (3) Move Aside and Move Motions, and (4) Other Work Segments.

Six different time values (0, .005, .010, .015, .020, and .025) appear on the table. These are in minutes but appear on the table without the decimal points and zeros for simplicity.

In addition to regular Brief Work-Factor®, an abridged Brief Work-Factor® method is used for very rapid application needed for estimating and similar work. The abridged version uses only three time values (.005, .010, .020).

SYSTEM APPLICATION:

In general, Work-Factor® operation times are based on the application of predetermined times to each individual motion required to perform a segment of work. To determine the operation time using Work-Factor®:

- Analyze the job to determine the necessary motions. Whether observed or visualized, the method must be verified by actual shop floor observation.

- Apply predetermined elemental times to each necessary motion.

- Total the times and make appropriate allowances for personal time, fatigue, unavoidable delays, and incentive potential.

° **Detailed Work-Factor®**: When analyzing an operation using this technique, the analysis for each Standard Element is written using symbols and numbers which describe the variables involved. All time values used in Detailed Work-Factor® are found in a single table called the Detailed Motion Time Table. Some of its features are:

  - Separate tables are provided for each Standard Element. Each table reflects the variables affecting the time for that element. (Times for parts of some Standard Elements, Simple Grasp for example, are obtained from the Transport Time Table.)

  - Time values are expressed in Work-Factor® Time Units (W-F Units). One Work-Factor® Time Unit equals .0001 minutes.

- Dimensional and other limits are expressed in terms of:

  -X: Over the previous value, up to and including X; and:

  >X: Greater than X.

Having written the elemental descriptions and analyses, the analyst, using the Time Table, must find the Standard Element involved. Locating the time value within the Table and using the variables described in the analysis, the analyst will prepare a standard as follows:

- Move bolt to hole in plate

Reach 18 inches to bolts	A18D	76
Gr bolt	Cyl 1/4 x 2	36
PP bolt	PP-0-50%	24
Move bolt to hole	A18SD	98
	Total	234
	or	.0234 minutes

The Reach and Move time values were taken from the Transport Table, the Grasp (Gr) from the Complex Grasp Table and the Pre-position (PP) from the Pre-position Table.

When the Motion Time Table for Finger is used, the analysis will appear as illustrated:

- Pick up 4 lb. building block and move it to stack.

Reach 24 inch to brick	A24D	86
Grasp brick	$F1W^2$	29
Move brick 35 inches to stack	$A35W^2SD$	171
	Total	286
	or	.0286 minutes

The Reach and Move time values were taken from the Transport Table and the Grasp time value was taken from the Motion Time Table for the Body Member used (i.e., finger (F)).

- **Ready Work-Factor®**: When analyzing an operation using this technique, the analyst documents each Standard Element using symbols and numbers which describe the variables involved. All time values used in Ready Work-Factor® are found in a single table called the Ready Work-Factor® Time Table. Some of its features are:

  - Separate tables are provided for each Standard Element except Disassemble. Each table reflects the variables affecting the time for that element. A section covering Body Motions and a few special motions is also included.

  - All time values are printed in red and are expressed in Ready Time Units (RU's). One Ready Time Unit equals 0.001 minutes.

  - Dimensional and other limits are expressed in terms of:

    -X: Over the previous value, up to and including X; and

    >X: Greater than X.

  - The time values are all simple numbers which follow an orderly sequence. Thus, frequently used values can be memorized.

Having written the elemental descriptions and analyses, the analyst, using the Time Table, must find the Standard Element involved. Locating the time value within the Table and using the variables described in the analysis, the analyst will prepare a standard as follows:

- Move bolt to hole in plate

Reach 18" to bolts	20-1	7
Grasp bolt	2	3
Pre-position bolt	0-50%	2
Move bolt to hole	20-2	9
	Total	21
	or .021 minutes	

The Reach and Move time values were taken from the Transport Table, the Grasp from the Grasp table, and the Pre-position time value from the Pre-position table. The Reach and Move parameters both required the application of Work-Factors®. The Move required one (20-1) and the Reach two (20-2). The 20 signifies the distance was within 20 inches (and greater than 10 inches).

An additional example is shown below:

- Pick up 4 lb. building brick and move it to stack

Reach 24" to brick	30-1	9
Grasp brick	1- x 2	4
Move brick 35" to stack	40-3	15
	Total	28
	or .028 minutes	

Again, the Reach and Move time values are taken from the Transport table with the grasp requiring one Work-Factor® and the Move two. The Grasp value was chosen from the Grasp table and multiplied by two because Ready Work-Factor® Rules require that Grasp values be doubled when the object weighs more than 3 pounds.

- **Brief Work-Factor®**: When analyzing an operation using this technique, the analyst lists the controlling Work Segments in the order of occurrence and applies the proper time values. (Note: Two-hand analyses are not used.)

Each description begins with the appropriate symbol for that Work Segment, followed by the corresponding Base Time Value and any Delete or Add-on times. The name of the object involved is then identified, followed by any other pertinent information desired (i.e., location, distance, tolerance, etc.). Each additional Work Segment is described in a similar manner, resulting in an analysis as follows:

> Reach 18 inches to 1/2 inch diameter by 2 inch long bolt in bin, grasp bolt, pre-position bolt, move bolt 12 inches to 9/16 inch diameter hole in metal bar, assemble bolt to hole in bar, release bolt, move bar (8 lbs.) aside 25 inches to fixture, assemble bar in fixture, (Tolerance 1/8 inch--Index required), release.

The analysis for this task is written as follows:

P20 + 5	bolt from bin	25
A10	bolt to hole	10
MA15	bar to fixture	15
A5+10	bar in fixture	15
	Total	65

or .065 minutes

In the example above, a "P" stands for Pick-up which includes reach and move, "A" stands for assemble, and "MA" for move aside.

- **Computerized:** The computer program, **WOCOM II**, developed to enhance Work-Factor® can be set up to use Detail, Ready, and Brief or any combination of the three. The computer logic is divided into four basic levels:

  - **LEVEL 4:** is supplied with the Work-Factor Motion Elements, which represent the motion elements and their corresponding predetermined time values as derived from the Work-Factor motion tables. The system may be set up to utilize either the Detailed, Ready, or Brief Work-Factor® tables or it may utilize any combination of these methods simultaneously. This is the controlling system level upon which all of the user data is established.

  - **LEVEL 3:** consists of Standard Data or task analyses which represent various work tasks performed by the user. They are constructed by the user from the motion elements contained in LEVEL 4, according to Work-Factor® procedures.

  - **LEVEL 2:** is comprised of Standard Data Summaries. These are combinations of standard data from LEVEL 3 and any additional motion elements required from LEVEL 4. Summaries are specific groupings of standard data items that are generic to a number of otherwise unique processes. They are intended to simplify work task references and facilitate the eventual creation of work standards.

- **LEVEL 1**: is the Work Standard. The work tasks or motion elements which apply to a specific work standard may be specified in either of two modes. The first mode is to specify a work standard by direct reference to the individual tasks or motions that it consists of. The second mode allows the user to create a menu of standard data from which the necessary tasks or motions may be selected. This menu is called a "Data Application Sheet" or more commonly a "Pre-Rate Sheet".

The WOCOM II system requires that the user is a trained Work-Factor® practitioner. Work analysis is performed in a manner identical to the manual procedures utilized. The automated system will facilitate the clerical procedures required of a Work-Factor® analyst and provide a permanent record of all work standards and task analyses.

WOCOM II automatically maintains the consistency of the user's data through the application of a feature known as "MASS UP-DATE". Whenever a change of task data is initiated by the user, WOCOM II will automatically adjust each standard rate which utilizes the modified task.

Some additional features of WOCOM II are:

- User supplied motion descriptions which can be user specified or default to present Work-Factor® terminology.

- Motions maintainable in user specified sequence may be modified and maintained by the user in order to accurately reflect actual work flow.

- "Package build" for easy entry of similar tasks can be created by copying existing items or by copying portions of existing items. The resulting packaged data can then be modified by exception to conform to a new standard or standard data requirement. This feature eliminates the need to key enter similar data and typically results in a considerable reduction in data entry effort.

- "Top down" detail task and motion listing are completely documented to the Work-Factor® elemental motion level. A multiple level, detailed process listing is available on demand.

- Standards listed by part number or department are organized by part number, operation number and department as a standard feature.

- Customized documentation for standards provides for customized work standard documentation specifically to the requirements of a particular client.

- Manufacturing routings or travelers are automatically created and updated.

- Where used reporting inquiries are available for all data elements.

- Line balancing calculates the most efficient number of stations on a line for a given output range, or the ability to have the computer calculate the optimum output rate and staffing for a given number of employees.

- Standard data archiving to store old standards off-line.

WOCOM II software was designed to run on a microcomputer and can be run on either the IBM AT or on a Seiko Series 8600 Business Computer.

The Work-Factor® system can be used to analyze any type of operation provided the proper level is used. **Detailed Work-Factor®** is used for **short-cycle, highly repetitive work, Brief Work Factor®** was designed for **estimating and for long-cycle operations**, and **Ready Work-Factor®** is used to measure **intermediate operations,** that is, those which fall between the very short and the very long cycle operations.

TRAINING/TECHNICAL ASSISTANCE:

To use Work-Factor®, the applicator must first attend a structured course which can be obtained through a variety of training alternatives. Various quizzes and a final exam are involved in all courses, with certification as an objective. The training alternatives available are as follows:

- A public training course at corporate headquarters or central locations throughout the U.S.
- A training course taught at the client location.

Each level of **Work-Factor®** has its own level of required hours of training as follows:

Detailed	120 Hours
Ready	80 Hours
Brief	10 Hours

Technical assistance is available at the Science Management Corporation training center.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
Training at SMC corporate headquarters	
Detailed Work-Factor® (4 weeks)	$ 2,000
Ready Work-Factor® (3 weeks)	$ 1,500
Brief Work-Factor® (1 week)	$ 500
Training on client premises with up to 12 participants	
Detailed Work-Factor® (6 weeks)	$30,000
Ready Work-Factor® (4 weeks)	$20,000
Brief Work-Factor® (1 week)	$ 5,000
WOCOM II Software(1)	$40,000

NOTE (1) The software price includes two weeks on client premises instructing Work-Factor® trained analysts in the application of the system through the computers.

COMPLIANCE WITH MIL STD 1567A:

Based on the data reviewed, it was found that the system had a bias which created standards consistently tighter when compared to standards developed using other predetermined time systems and/or time study. Because of this identified bias, and based on the data provided, the theoretical accuracy of the system was found not to be in compliance with MIL STD 1567A. It should be noted that, although the theoretical accuracy was found to deviate from the accuracy level presented by the MIL STD, by properly applying leveling techniques, which are accepted by the MIL STD, the system could be used to develop standards which are in compliance with MIL STD 1567A. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.
- A record of observed or predetermined time system time values used in determining the final standard time.
- Provision of an audit trail down to the elemental standard time level.

Those basic requirements as specified in the MIL STD which were in question are as follows:

- All Type I standards must reflect an accuracy of ± 10% with a 90% or greater confidence at the operational level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the Work-Factor® predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- The system allows for standards development using any combination of three levels of detail based on the types of operations being analyzed and the level of accuracy desired.

- The system vendor provides standard data for commonly used equipment and operations.

- The system has values for mental process times.

- Allows for use of user-defined formulas.

- Easy to apply.

- Computerized application provides improved speed, accuracy, and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" methods-improvement scenarios.

- System times reflect an average experienced operator working at an above normal pace.

SYSTEM USERS:

Based on data supplied by the system vendor, a breakdown of system users by manufacturing type is as follows:

APPLICATION TYPE	NUMBER OF COMPANIES
Electrical	78
Metal Fabrication	110
Assembly	151
Machining	210

REFERENCE SOURCE:

Science Management Corporation

UNIVEL®

CONTACT: Richard T. Jennings, Senior Vice President
COMPANY: Management Science, Inc.
ADDRESS: P.O. Box 1310, 591 Alamo Pintado Road, Solvang, CA 93463
PHONE: (805) 688-2488

SYSTEM HISTORY:

Development of the **UNIVEL®** system and its universal math models began in 1955 in the United States. The idea of universal formulas stemmed from work being done on a statistical sampling program to develop time and cost formulae for material-handling applications.

A group of manufacturing engineers was assigned to develop standard times for macroscopic, elemental manual work functions. The initial sample studies consisted of 14,400 elemental observations taken randomly over a period of six months, and were of 360 different manufacturing operations in machining and assembly.

Based on these 14,400 elemental observations, geometric formulae and curves were developed to predict average elemental times within 5%, 99.7% of the time, according to the system vendor. Originally, comprehensive standard data books were developed from these curves, and applications of elemental standards and methods instruction were developed for machining and assembly operations.

In 1964, Management Science, Inc. was founded for the purpose of developing computer software utilizing the universal formulae. The initial installation of this software, called UNIVEL®, was completed in 1966.

SYSTEM DESCRIPTION:

UNIVEL® is a software system which generates detailed operator instructions and the associated standard times, and places this information, along with related cost and engineering information, into computer files for use in manufacturing production planning and control applications. The UNIVEL® system utilizes a proprietary algorithm to define manual work elements.

The UNIVEL® software system uses group-technology techniques to develop families of parts with similar processes, and classifies operations that have multiple use in fabrication and assembly.

Elemental standard times are generated by the computer, utilizing the universal formulae. Because the computer recalculates a standard each time it is accessed, it eliminates the use of standard data. In addition, the system does not require any averaging due to the fact that exact job variables can be coded into the system.

When developing standards with UNIVEL®, the universal formulae automatically compensate for the following: interdependency of elemental functions; weight, sizes and complexity of objects; hand, body, mental and visual element combinations; and inertial and reactional circumstances.

UNIVEL® is sold as a module in computer-integrated manufacturing (CIM) software systems. Management Science, Inc. markets two CIM systems: MICROCAM for personal computers and microcomputers, and UNIVATION® for mainframe computers.

MICROCAM is designed to aid in the planning and control of the manufacturing process. MICROCAM contains seven integrated software modules which can be used separately or together. The seven modules are as follows:

- **UNIVEL®**: methods instructions, associated standard-time and data-base generation. The data base has 11 restriction finders by which it can be accessed (i.e., material, machine, shift, etc.). Mass updating is also available.

- **UNICOMP**: adds, deletes, or changes any additional formulae needed in the development of elemental standard times.

- **MIMICOMP**: provides the ability to develop, store and retrieve mini sets of methods and processes that are common to families of parts.

- **UNIFORM**: allows the simulation of manufacturing procedures which are long-cycle or non-repetitive in nature (i.e., movement and distribution of materials, warehousing, material handling).

- **METSET**: allows one to build super sets of manufacturing procedures by using families of mini sets so that the engineer can input large fabrication procedures or assembly procedures.

- **MICROCOST**: provides the capability of generating both standard and current costs by using material, labor, fixed and variable burden, and setup rates.

- **MICRORTG**: stores temporary routing information on parent, machine used, groups of machines used, labor applied and labor class, department, division, by individual part operation, part, and subassembly.

The **UNIVATION®** system utilizes computer software to aid in the design and modification of products and processes, the operational control of fabrication and assembly, management of resources, and generation of accurate and timely flow of information. The 10 modules of UNIVATION® can be used separately or as an integrated system and can be added at any time. These modules are as follows:

- **UNIVEL®**: Methods instruction, associated standard-time and data-base generation. The data base has 11 restriction finders by which it can be accessed. (i.e., shift, machine, part, etc.).

- **MULTICOMP**: Mass updating system for methods, standards, and data bases.

- **UNICOMP**: An algebraic filter program for formula programming.

- **VARICOMP**: An automatic, variable-methods input editing system.

- **UNIPLAN**: Balancing system for assembly line or facility scheduling and loading for manufacturing operations.

- **P-A-R**: Performance, audit and review system for performance reporting and trend analysis to reflect current conditions.

- **UNIFORM**: Statistical linear-regression system to generate standards for jobs such as shipping, receiving, tool control, etc.

- **UNICOST**: System for automatically generating direct and standard product costs at an operational level.

- **MINICOMP**: Utilizes engineered methods modules and unique variables to establish methods and set standards.

- **UNI-CAM**: Interactive variant process-planning system using a unique data base management system.

SYSTEM APPLICATION:

The first step in developing standards using UNIVEL® is to observe and document the method. If visualization is used, the method must be verified by actual shop floor observation.

Next, there are five measurements the analyst must document as follows:

- **Distance from** - the distance an object is moved from.
- **Distance to** - the distance an object is moved to.
- **Weight** - of the object.
- **Location** - requires choosing a value of one through six, indicating the type of location.
- **Difficulty** - requires choosing a value of one through nine, indicating the level of difficulty.

The analyst enters the above information, as well as the method and operation information, onto a computer data sheet which is used as a reference for entering the data into the computer. The computer then calculates the standard time for the operation. An example is shown below.

NO.	ELEMENT DESCRIPTION	FREQ.	HRS/PC	MIN/PC
1	D611 CLOSE (5) HITS			
2	MOVE ARBOR 8 IN. TO POSITION ON PART	1/ 1	.0001788	.01073
3	MOVE ARBOR 15 IN. TO POSITION IN DIE	1/ 1	.0003030	.01818
4	MOVE FOOT 2 IN. TO TRIP PEDAL & START CYCLE	1/ 1	.0000724	.00434
5	PRESS CYCLE (1) HIT	1/ 1	.0001667	.01000
		TOTAL	.0034479	.04325

UNIVEL® can be used to measure **short-** or **long-cycle** operations that are either **repetitive** or **non-repetitive, with** or **without variations.** The UNIVEL® system is best-suited for **fabrication**, or **assembly operations.**

The MICROCAM system runs on an IBM XT, AT and other compatible computers. The PC version has the ability to integrate with mainframe software.

The UNIVATION® modules will run on all hardware that supports ANS COBOL, such as IBM Systems 3 through 3300, HP 3000, DEC VAX, TI 990, and DG Eclipse.

TRAINING/TECHNICAL ASSISTANCE:

All training for software modules offered by the vendor is self-paced using training manuals and/or "help" screens built into the software. An exam is available upon completion of the training and, based on the score received, the student is certified.

If the client desires, the vendor will provide guided instruction at either the vendor's facility or the client's location.

Technical assistance is available to the client at any of the vendor's offices.

SYSTEM COSTS:

Software costs for systems using UNIVEL® range from $16,500 for MICROCAM with no modules to $200,000 for a mainframe system. Each system is tailored to the client's specific needs.

A maintenance package is available which guarantees the user all system updates for a fee of 1 percent of the original software cost per month.

Any training desired by the client will be provided at $1500 per week at the vendor's facility or on a per-client basis at the client location.

COMPLIANCE WITH MIL STD 1567A:

The UNIVEL® predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.
- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the UNIVEL® predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- The system is easily applied.

- Computerized application provides improved speed, accuracy and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" methods-improvement scenarios.

- The system will accept and manipulate data developed by utilizing other work measurement systems or techniques.

- Generates good documentation of the work sequence or process being analyzed.

- The system cannot be manually applied.

- Use of the system requires a fundamental knowledge in the use of computers.

- Past technical assistance provided by the system vendor showed limited computer-hardware knowledge.

SYSTEM USERS:

The vendor states that they have served 580 companies in a variety of applications as follows:

- Aerospace
- Automotive
- Electronic
- Oil
- Consumer Products
- Construction Equipment
- Gasoline and Diesel Engines
- Computer Equipment
- Printing

REFERENCE SOURCE:

Management Science, Inc.

MODAPTS PLUS™

CONTACT: Donald L. Gerber, President
COMPANY: Management Research Frontiers
ADDRESS: 160 Caldecott Lane, Suite 214, Oakland, CA 94618
PHONE: (415) 548-5283

SYSTEM HISTORY:

MODAPTS™ was developed in Australia by a research team that analyzed more than 10,000 tasks in business, industry, and government on which accepted standards had been developed using time study, Autorate, MCD, MSD, MTM-1, MTM-2, WorkFactor® and other systems. Each task was restudied with several of the above techniques. Reconciliation of differences in the results required physiological, psychological, and engineering research.

The result of the above studies provided insights into the development of a new motion-time unit and a new energy-time unit, and provided the basis for the development of a work measurement system. One component was a mathematical model identifying the human capabilities in the work environment, and was called the Energy Model of Man (EMMA).

In 1966 the first of the new systems, Modular Arrangement of Predetermined Time Standards, MODAPTS™ was introduced. OFFICE MODAPTS™ for white-collar work was introduced in 1969, followed by TRANSIT MODAPTS™ for heavy physical work in 1974.

The three systems were combined into a single system called MODAPTS PLUS™, introduced in 1981. Supporting software for microcomputers was developed in 1984, making the application faster, easier, and more consistent. Commercial software support was first offered in 1984.

SYSTEM DESCRIPTION:

MODAPTS PLUS™ is a predetermined time system which describes work in human terms rather than mechanical terms. It can be applied either manually or by computer. MODAPTS Plus™ is a trademark name for systems developed by Heyde Dynamics Pty. Ltd. of Australia. All rights to the system are held by the

nonprofit International MODAPTS™ Board, Inc., (IMBI), which has 12 individual members worldwide. Management Research Frontiers Inc., (MRF) is the North American publisher of software and distributor of MODAPTS PLUS™ materials, whose president is a member of IMBI.

MODAPTS™ is based on the premise that the time taken for any body movement can be expressed in terms of a multiple of the time taken for a single finger move. The time taken for a finger move, and thus the **motion-time unit**, for MODAPTS™ is called a **MOD.** A MOD is a unit of work whose value assumes that the motion is carried out with minimal expenditure of energy and that the time to move is proportional to the fifth root of the moment of inertia of the body part moved.

The time value of a single MOD may be altered in order to attain accuracy in a given situation, but the relative values of different motions remain the same and are embedded in the codes.

MODAPTS PLUS™ is comprised of 21 basic codes which are alpha-nmemonic (i.e., G = Get). The alpha code is combined with a number which is the motion-time-unit value, or MOD value, of that particular code (i.e., G1). A total of 92 alphanumeric codes comprise the entire data table or data card, which may be applied in almost any work situation.

MODAPTS PLUS SUITE™ is computerized MODAPTS PLUS™ and it operates on PC-compatible computers. IMBI also licenses use of the MODAPTS PLUS™ trademark and MODAPTS PLUS™ table of elements to selected software designers, who offer other software to support application and maintenance. Among these is Workfile™.

MODAPTS PLUS SUITE™ consists of two major sections as follows:

- **FULL/COMPACT:** used to analyze activities. Two help levels are provided. The analyst develops a study using menu choices relating to appropriate boxes on the data card. Element-code generation, simultaneous motions, load factors, process time, and data derived elsewhere are all handled automatically. Titles, comments, and allowances may be entered to

produce a documented procedure. The computer makes all calculations required for measurement and quantitative analysis. Studies may be stored or printed out. The software allows for the development of "block data" which may be nested or chained to produce higher-level studies. More than 20 levels may be stored and retrieved.

- **RECOVERY**: analyzes energy expenditure and deals with the energy required to GET an object at any height, gain control of it, carry or move it to another location, and PUT it where it has to go. Two help levels are provided.

WORKFILE™ is a dedicated data-base management system designed for organizations which must build and maintain a large library of standards. Workfile™ can be run on IBM PC-XT, AT or compatible computers.

Features included in WORKFILE™ are as follows:

- Generates new standards using:
  - a built-in MODAPTS™ element generator;
  - data from any other standards system;
  - data from time studies;
  - process time.

- Uses a building-block approach to develop block data and multilevel macro standards.

- Automatically reflects changes in any block throughout the system.

- Incorporates existing work standards.

- Incorporates process time and variable allowances.

- Allows full description of all work blocks and elements.

- Provides automatic professional documentation.

- Prints all blocks or selected groups of blocks.

- Performs automatic global update of all standards to reflect any changes in their constituent block data.

- Prints blocks affected by an update.

- Generates print files which can be printed locally in background mode or transmitted for remote printing.

- Does a recursion check to warn of situations where blocks indirectly call ("quote") themselves.

- Provides a "Where-found" list showing blocks which call any named block, both directly or indirectly, through intermediary blocks on different levels.

In summary, MODAPTS PLUS™ has the capability to analyze the majority of work situations. It is feasible to use the system to evaluate different ways of performing the same task with proposed changes in method or equipment, and the way different people perform the same task with the same equipment.

SYSTEM APPLICATION:

MODAPTS PLUS™ can be applied either manually or by computer. The same basic principles apply to both methods except that the computer provides prompts to aid the user, contains additional features, and is estimated by the vendor to be 20% to 50% faster than the manual systems.

- **MANUAL:**

  To initiate a study, the analyst should begin by documenting the method of operation and then applying the MODAPTS™ codes. Whether observed or visualized, the method must be verified by actual shop floor observation. MODAPTS PLUS™ requires the use of a single data card which displays ranks and files of boxes with pictures, alphabetics, and numerics. The pictures depict parts of the body; the alphabetics are single alphabetics and

alpha-mnemonic (i.e., G = Get); the numerics are all integers and are duplicated such that one column has values of "1", another column has values of "2", and so on.

The analyst observes or projects the body parts used to carry out an action or series of actions, looks up or recalls from memory the elements on the data card, and writes them down on the analysis form. The element times are then added, multiplied by the frequency, and divided by seven to obtain the normal time in seconds. The total is divided by seven as the motion-time units used to describe the elements was a finger move called a MOD. One MOD was determined to be 129 milliseconds, or 7.75 MODs per second. Assuming a rest or fatigue allowance of 10.75%, the basis becomes 7 MODs per second. Allowances can then be added to obtain the standard time. (See Example Activity.)

- **EXAMPLE ACTIVITY**:

  Seated person sees on the floor a piece of paper with writing on it. Person gets up, walks across, picks up the paper, stands and reads 18 words, and then returns to the seat, pocketing the paper on the way. A total of 14 paces is taken.

LINE	ACTIVITY		VALUE	FREQ.	PRODUCT
1	Sit & stand	S	30	1	30
2	Walk	W	5	14	70
3	Bend & arise	B	17	1	17
4	GET paper	M2G3	5	1	5
8	Read Silent	R	2	18	36
					158

Cycle Time = 158 ÷ 7.75 = 22.6 seconds

° **COMPUTER**:

- **MODAPTS PLUS SUITE™**

  The MODAPTS PLUS SUITE™ has been written in BASIC, and versions are available for several of the more common microcomputers and consist of two major sections as follows:

°° **FULL/COMPACT**: used to analyze activities. The analyst thinks of the body part(s) used to carry out some action or series of actions and follows menu choices to make entries. Simultaneous motions, load factors, process time and data derived elsewhere are all handled automatically. Titles, comments, and allowances may be entered to produce a documented procedure. A subtotal display is available at any stage for review, editing, etc. The computer makes all calculations required for measurement and analysis. Studies may be stored or printed out. Studies may be stored as "block data" which may be "nested" or "chained" to produce macro studies or super operations.

An example of an analysis using MODAPTS PLUS SUITE™, FULL/COMPACT is shown below:

°° ACTIVITY: CHANGE TOPS ON BOTTLE.

LINE ACTIVITY	VALUE		FREQ.	MODs	SECONDS
1 GET & PUT 2 oz. bottle on table	M2G1 M2P0	5	0	0	0
2 PUT hand on bottle cap	M2P2	0	0	0	0
3 LAST TWO TOGETHER "SIMO"	5		6	30	3.87
4 GET AND PUT twist off old cap	M1G0 M1P0	2	24	48	6.19
5 (E)XTRA FORCE for first twist only	X4		6	24	3.1
6 GET AND PUT discard old lid	M1G0 M2P0	3	6	18	2.32
7 GET AND PUT S/L on bottle	M1G1 M1P0	3	24	72	9.69
8 PUT 2 ox. bottle in box on table	M4P2	6	6	36	4.64
				228.0	29.4

1 Cycle Time	In Sec.	In Min.	In 0.001 Hrs.	Cycles/Hour
No Rest :	29.41	0.4902	8.170	
With Rest :	32.57	0.5429	9.048	111

°° **RECOVERY**: Relates to energy expenditure.

The second part of the program, RECOVERY, applies to physical work. This section deals with the energy required to GET an object at any height, gain control of it, carry or move it to another location, and PUT it where it has to go. Walking is included, on the level, up or down steps, and up or down ramps, with the program assuming that the person walks back empty-handed.

The time is calculated in MODs. The energy requirement is calculated in Energy Time Units (ETUs) which are also expressed in MODs, based on 12.5 joules/MOD or a rate of 87.5 watts assuming a 10.75% allowance. The energy calculation takes into account the physical movement of both body and article moved, and compares the energy expenditure with the body's energy reserves. At the end of the calculation, the program displays its findings.

An example of the output for a high-energy task might be as follows:

TASK: Pick up 60 lb. object from floor, walk 25 steps, and place the object on the floor.

RECOVERY ANALYSIS

M-T-U = 168	Location	Type	With Steps
E-T-U = 239	Get = 1	3	Horizontal distance = 25 feet
Mass = 60 lb.	Put = 1	4	No stairs/ramps

21.8 seconds is the expected one-cycle time.

105.4 is the expected cycles per hour. This includes rest and personal time, and includes any recovery time necessary. 20 cycle(s) should be followed by time for energy recovery.

4.4 minutes energy-recovery time is appropriate.

Total allowances are 42.3 percent.

M-T-U represents "motion time units" and E-T-U represents "energy time units."

The same example, shown below assuming a 120-lb. object, shows how the energy recovery time required changes and therefore the required allowance changes:

RECOVERY ANALYSIS

	Location	Type	With Steps
M-T-U = 201	GET = 1	3	Horizontal distance 25 feet
E-T-U = 430	PUT = 1	4	No stairs/ramps

26.1 seconds is the expected one-cycle time.

58.6 is the expected cycles per hour. This includes rest and personal time, and includes any recovery time necessary.

2 cycle(s) should be allowed by time for energy recovery.

1.5 minutes energy-recovery time is appropriate.

Total allowances are 113.9 percent.

According to the system vendor, the time required to set a standard using MODAPTS PLUS™ has been determined to represent a ratio of 30:1 for the manual system and is 20-50% faster using a computerized version once the method has been defined.

MODAPTS PLUS™ can be used to establish work times in a number of situations including processes, job shops, and assembly. It can be used for scheduling, costing, staffing, establishing price rates, design, and evaluation of workplaces, layouts, methods, procedures, task assignments, equipment, etc.

MODAPTS PLUS™ can be used to evaluate operations which are either **short-** or **long-cycle**, **repetitive** or **non-repetitive**, **with** or **without variations.**

Minimum hardware requirements for computerized MODAPTS PLUS™ include either a personal computer or a microcomputer which can run on IBM PC-DOS 2.00 or higher, or the MS-DOS equivalent.

TRAINING/TECHNICAL ASSISTANCE:

Training in MODAPTS PLUS™ can be obtained in a variety of ways through MODAPTS PLUS™ Value-Added Resellers (VAR) within both academia and consulting and are located throughout the United States as follows:

- A seminar-workshop taught by a VAR instructor at the client's location (18 - 32 hours plus about 80 hours application assistance).

- A seminar-workshop taught by a VAR instructor at an open-registration course at an announced location (22 - 40 hours).

- A seminar-workshop taught by a qualified client instructor at the client's location (18 - 32 hours plus about 80 hours application assistance).

The vendor recommends that the best approach is to conduct the training at the client's location with supervised on-the-job training to follow the lecture course. Each instructor provides his own examination for students, and certification in MODAPTS PLUS™ is offered but is not required.

Technical assistance is available to users through Management Research Frontiers (MRF) and the International MODAPTS™ Board Incorporated (IMBI).

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
Training	$ Per-client Basis
License for system use and manual	$ 50.00 per student
Software	
MODAPTS PLUS SUITE™	$ 595.00
WORKFILE™	$15,500.00

COMPLIANCE WITH MIL STD 1567A:

The MODAPTS PLUS™ predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of $\pm$ 10% with a 90% or greater confidence at the operational level.

- Documentation of an operations system.

- A record of standards practice or method followed when the standard was developed.

- A record of rating or leveling.

- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the MODAPTS PLUS™ predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- Computerized application provides improved speed, accuracy and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" methods-improvement scenarios.

- The system will accept and manipulate data developed by utilizing other work measurement systems or techniques.

- Incorporates process-time formulas and variable allowances.

- Generates good documentation of the work sequence or process being analyzed.

- Past user support provided by the system vendor has been exceptional.

- The system has a finite number of elements from which to choose for assignment of time values to an element of work, which causes some applicator judgment.

SYSTEM USERS:

The vendor was unable to provide users by manufacturing type, but did provide data which states that MODAPTS PLUS™ is being used in more than 30 countries in a variety of industries as follows:

- Automotive
- Electronic
- Financial
- Defense
- Medical

REFERENCE SOURCE:

Management Research Frontiers

AM COST ESTIMATOR

CONTACT: Dr. Phillip F. Ostwald
COMPANY: COSTCOM Inc.
ADDRESS: 6682 Whaley Drive, Boulder, CO 80303
PHONE: (303) 494-3806
DISTRIBUTOR: American Machinist
COMPANY: McGraw-Hill Company
ADDRESS: 11 West 19th, New York, NY 10016
PHONE: (212) 512-3100

SYSTEM HISTORY:

The data provided in the **AM COST ESTIMATOR** book and used in the software package was initially copyrighted in 1981. It was used for consulting purposes by the system vendor, COSTCOM, INC., prior to that time. The data has been developed by the author of the system, Dr. Phillip F. Ostwald.

The current version of the book, AM COST ESTIMATOR, is the 1985-1986 edition. The 1987-1988 edition is being printed and will be available from American Machinist of McGraw-Hill in early 1987. Both editions are compatible with the AM COST ESTIMATOR software, which has been available since September 1985.

SYSTEM DESCRIPTION:

AM COST ESTIMATOR is a standard data system that provides both cost and time data for estimating sawing and cutting, molding, presswork, marking, hotworking, turning, milling, drilling, boring, broaching, grinding, gear cutting, thread cutting and form rolling, welding and joining, heat treating, deburring, nontraditional machining, finishing, assembly, inspection, electronic fabrication, packaging and tooling. The system is available in either a manual or computerized version.

The manual version is a reference book, AM COST ESTIMATOR, 1985/1986 edition, by Phillip F. Ostwald, containing tables of data for a wide variety of production equipment that can be used to estimate both the cost and time requirements of direct labor for a wide variety of manufacturing activities. With each new edition, the author introduces new equipment into the data base.

In the section, "Element Estimating Data", information is provided for estimating direct-labor setup and cycle time associated with specific equipment processes, or benchwork applications. The methods of measurement used to establish the elemental estimates include time study, predetermined motion-time data systems, laboratory investigation, manufacturer's recommendations, and judgment.

The approach assumes that differences among trained operators for specific setup, machine process, or bench activities are minor for purposes of estimating. However, for unique or significantly different activities, dependent upon some special machine process, the book provides individual treatment.

The AM COST ESTIMATOR package is a ready-to-use data base containing the necessary data and application methodology for estimating manufacturing operations.

The AM COST ESTIMATOR system contains 26 operations, over 135 equipment types, and 16,000 elemental data. There are over 700 equations and constants in the operational cost section. A listing of approximately 75 basic material costs and 3100 productive-hour costs for the 23 Bureau of Labor standard metropolitan statistical regions is provided.

The vendor states that the system is suited for fabrication, assembly, process, and electronic applications.

The time- and cost-estimating data contained in the book and software can be used for tool and model building, and production-run quantities of one on up for contract manufacturers. The vendor states that, most generally, the data relates to mid-sized batches, ranging from 15 to 5000 units. There are exceptions, depending upon the nature of the fabrication or manufacturing activity.

SYSTEM APPLICATION:

The AM COST ESTIMATOR system can be applied either manually or by computer. While the specific application procedures differ between the two, the theory of the system's application is the same. The steps required for developing work standards using the AM COST ESTIMATOR - Element Estimating Data are as follows:

- Analyze the manufacturing activity and select the operations for which the standard will be based.
- Define operational elements.
- Match the elements with the system's estimating standard data tables.
- Document and/or input the element number; machine, process, or bench; table number (from book or software); and element description.
- Document or input selected setup times.
- Document or input selected cycle-element times.
- Compute unit estimate; determine lot size, piece per hour, etc.
- Adjust standard for productivity levels.
- Verify with actual shop floor observation.

The vendor states that the data is best suited for operations which experience variations and where an analyst must select those elements which created variations in the operation.

The hardware required for operating the AM COST ESTIMATOR computerized package is an IBM Personal Computer or compatible. The PC can be either fixed-disk or have two disk drives. The RAM should be at least 256K, although 640K will allow for the development of longer work standards.

TRAINING/TECHNICAL ASSISTANCE:

The vendor states that a self-study approach is adequate for learning how to use the AM COST ESTIMATOR. The first section of the book provides a self-study discussion. There are over 350 detailed examples. Certification is not required for use of the manual or computerized system. If requested, the system vendor, COSTCOM, INC., will provide on-site training. In addition, COSTCOM, INC. periodically provides training seminars in conjunction with the Society of Manufacturing Engineers.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
AM COST ESTIMATOR (Text) 1985-1986 Ed.	$ 97.00
AM COST ESTIMATOR (Software Package)	$795.00
AM COST ESTIMATOR (Demo Package)	$ 20.00

COMPLIANCE WITH MIL STD 1567A:

The AM COST ESTIMATOR predetermined time system is in compliance with the specific requirements set forth in MIL STD 1567A. Based on our review of statistical backup data provided by the vendor, the system will theoretically generate standards with an accuracy of at least ±10% at a 90% confidence level. (See System Accuracy Section). Those specific requirements which have been met are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.
- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.

- A record of rating or leveling.

- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the AM COST ESTIMATOR predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- System is easily learned and applied.

- Manual application is cost-effective.

- The system provides extensive cost and time estimates for commonly used equipment and operations in the areas of machining, welding, fabrication and assembly.

- Computerized application provides improved speed, accuracy and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" methods-improvement scenarios.

- The system allows for one material rate and one labor rate per operation estimate, which may affect an estimate's accuracy for operations involving multiple material or labor rates.

- Operations estimates developed by using the computerized version are limited in length to approximately eight computer-print pages.

- No tooling estimate data currently exists; however, the system vendor states that it is planned.

- Costing updates occur biannually.

- The data in the tables can be modified by the user, which can eliminate the system's backup data integrity.

SYSTEM USERS:

The AM COST ESTIMATOR standard data system, including both the manual and computerized versions, has been applied in over 5,000 manufacturing environments. Current users of the system include: job shops, product manufacturers, auto industries, sheet-metal concerns, machine shops, original equipment suppliers, machine-tool builders, aerospace firms, electronic fabricators/assemblers, and Department of Defense depots and maintenance facilities.

REFERENCE SOURCE:

American Machinist of McGraw-Hill.

METCUT

CONTACT: Susan M. Moehring, Manager, Machinability Data Center
COMPANY: METCUT Research Assoc., Inc., Manufacturing Technology Div.
ADDRESS: 11240 Cornell Park Dr., Cincinnati, OH 45242-1812
PHONE: (513) 489-6688

SYSTEM HISTORY:

The development of the **Metcut Machining Data** began in the 1950s and was developed from two major sources and then submitted to industry "experts" for review. Having verified the data, it was initially published in 1960 in the book Machining Data Handbook and has been updated and republished in 1966, 1972, and 1980.

The Metcut Machining Data was first computerized in 1984 and enhanced versions are continually being developed.

SYSTEM DESCRIPTION:

The latest edition of Metcut's **Machining Data Handbook**, published in 1985, provides machining recommendations for over 1500 materials and 80 operations. Materials include various hardness ranges and metallurgical conditions including heat treatments, and are divided into 61 major material groups and subgroups. All materials are indexed in alphabetical and numerical listings and by the material group in which the alloy appears. In addition, where applicable, the Unified Numbering System designation has been provided.

Data tables presented in the book are organized by material type, hardness, metallurgical condition, and the desired depth of cut. The data provided for each variation in both U.S. and metric units includes:

- Cutting speed
- Feed rates
- Tool material type

Operations represented in the Machining Data Handbook include:

- Turning
- Milling
- Drilling, Boring, & Operations on holes
- Tapping
- Planing & Broaching
- Sawing & Cutoff
- Gear Cutting & Gear Grinding
- Grinding
- Mechanical Nontraditional Machining
- Electrical Nontraditional Machining
- Thermal Nontraditional Machining
- Chemical Nontraditional Machining

Additional information is provided in the handbook regarding areas such as tool materials and geometry, cutting fluids, power and force requirements, surface technology, machining guidelines, grinding and abrasive machining, numerical control machining, computer-aided manufacturing technologies, machining standards, and machine chatter and vibration.

In 1985, Metcut published a software program, **CUTDATA™**, which provides a computerized version of the Machining Data Handbook. CUTDATA™ provides recommendations for cutting speeds, feed rates, tool material and geometry, and cutting fluids.

In addition to retrieving machining data, CUTDATA™ converts units between English and metric, and converts standard speed and feed rates to machine settings in RPM and inches per minute.

CUTDATA™ can also interpolate data to obtain machining recommendations for depths of cut other than the standard handbook recommendations using a preprogrammed computer algorithm.

Calculation of horsepower requirements for the recommended machining conditions is accomplished automatically. A comparison can be made of the horsepower required for each cut to the power limitations of the machine tool to be used.

With CUTDATA™, the data can be updated and expanded to reflect the user's machining experience. Information specific to the user's machining operations, such as tooling and vendors used, can be added to the CUTDATA™ data base.

In addition to CUTDATA™, a second software system available from Metcut is **CUTTECH™**. CUTTECH™ is a software system which uses Metcut's machining data and can be customized to a specific company or plant. Essentially, it provides a machining technology data base for detailed planning of machining operations with the following capabilities:

- Machine Tool Selection
- Cutting Tool Selection
- Cut Recommendations
- Speed/Feed Recommendations
- Machining Time and Cost Estimates
- Horsepower, Torque, and Surface Finish Estimates

Information regarding a company's specific machine and tool types and identifying numbers is incorporated into CUTTECH™. In addition, the system includes a module for manually entering process data for non-machining operations.

CUTTECH™ can be developed as a stand-alone system or can be interfaced with other existing CAM application software such as process planning, time standards, or tooling data bases.

In addition to CUTDATA™ and CUTTECH™, Metcut has developed the **CUTPLAN™** software system. CUTPLAN™ provides a framework to incorporate the operation planning details, provided by CUTTECH™, into a standardized routing. CUTPLAN™

utilizes a flexible Group Technology coding concept to organize process plans. CUTPLAN™ is a system of generic process-planning software modules with tailored applications for specific production facilities.

SYSTEM APPLICATION:

- **Handbook**

  The first step in using the data found in the Machining Data Handbook is to locate the tables relating to the machining operation being analyzed. Next, locate the type of material to be used, its hardness and metallurgical condition, and the desired depth of cut. Once the corresponding location is identified in the table, the user looks across the data to identify the appropriate speed, feed, and tool material.

- **CUTDATA™**

  In order to find the same information using the CUTDATA™ software system, the user follows interactive prompting messages that lead through the machinability data retrieval and updating processes.

  The information prompted for the user is as follows:

  ° Which machining operations?
  ° Which workpiece material?
  ° Which tool material?
  ° What are workpiece and cutting dimensions?

  The computer prompts the user with a question and provides choices which the user selects with the cursor. A sample of the questions for retrieving machinability data for a turning operation is illustrated below.

  - Which machining operation?

    °° For which machining operation group?

    °° For which type of this machining operation?

- Which material family?

  °° Enter Material Designator -->

- Which hardness and condition?

- Which tool material?

Once the above prompts have been completed and appropriate information has been chosen, CUTDATA™ then asks for the workpiece and cutting dimensions. In the turning operation example, the program would ask for the workpiece diameter in inches.

The program then displays a table as follows:

CUTDATA™ - Machinability Data   Workpiece Diameter: 4.000 in.
                                                 Cut Length: 8.000 in.

TURNING, SINGLE POINT AND BOX TOOLS

ALLOY STEELS, WROUGHT
Low Carbon
4012
175-225 BHN HOT ROLLED, ANNEALED OR COLD DRAWN

HIGH-SPEED STEELS   Efficiency: 80% *

DEPTH OF CUT	SPEED	FEED	TOOL MATERIAL	CUT TIME	MATERIAL REM. RATE	HORSE-POWER
in.	fpm	ipr	AISI	min	cu in/min	hp *
0.040	135	0.0070	M2, M3	8.86	0.45	0.64
0.150	105	0.0150	M2, M3	5.32	2.83	3.97
0.300	80	0.0200	M2, M3	5.24	5.76	8.06
0.625	65	0.0300	M2, M3	4.30	14.62	20.47

Once the table has been displayed, the user may manipulate the data or retrieve additional information using one of the data table functions as follows:

- **Interpolate**: allows the user to view data for a depth of cut that falls in between two original table values.

- **Calculator**: allows the user to change feed and/or speed data and calculates the resulting effect on metal removal rate, cutting time, and horsepower.

- **Maintenance**: allows the user to delete from or add to data tables any interpolations or calculations made, or other data.

- **Machine Settings:** allows the user to express speed data in RPM and feed rates in inches per minute.

- **Cut Dimensions**: allows the user to modify the workpiece and cutting dimensions.

- **Metric**: allows the workpiece and cutting dimensions to be input using English or metric units.

- **Tool Geometry**: describes the tool geometry requirements.

- **Cutting Fluids**: cutting fluid recommendations, including vendor names, are listed for the operation being analyzed.

- **Print**: prepares a printed hard copy of the data table or creates an ASCII format disk file.

CUTDATA™ basically uses a series of prompts to guide the user to the appropriate location in the table data and, once there, allows the user to manipulate the data to meet specific requirements or to test "what-if" changes.

CUTDATA™ has been designed to run on an IBM PC, PC/XT, PC/AT or any compatible computer which accepts DOS 2.0 or higher. Workstation and mainframe versions are also available.

- **CUTTECH™**

The CUTTECH™ software provides the user with textual descriptions of his choices and, in some cases, graphical descriptions as well. The software interactively prompts the user for the type of machine tool, workpiece material, and cut description. The computer then automatically selects machine tools and a specific cutting tool for the operation and asks the user for approval. Once the selected tools are approved, the software will divide the volume of material to be removed into individual passes and assign speeds and feeds for each pass. The horsepower requirements are then calculated and displayed to the user who then can accept or reject the cutting conditions. The system displays a table to the user which shows the machine tool, cutting tool, dimensions of each cut, speeds and feeds, metal removal rate and machining time and cost. This table can then be printed and the recommendations can be incorporated into an NC program or used to make up the worksheet that the machine operator will follow.

CUTTECH™ is customized for each user so that machine and cutting tool information and coding specific to the user is input into the CUTTECH™ data base.

Both CUTDATA™ and CUTTECH™ have the capability to be interfaced with existing manufacturing and/or design systems.

TRAINING/TECHNICAL ASSISTANCE:

The Machining Data Handbook and the CUTDATA™ software system are both completely self-taught. Detailed instructions are provided with both. A user's manual is provided with each CUTDATA™ package.

CUTTECH™ training is included with the customizing process as the system is developed for each user.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
Machining Data Handbook	$ 160.00
CUTDATA™ SYSTEM	
° PC Version	$ 895.00
° Workstation/Mainframe	$ Per Client
CUTTECH™ SYSTEM	$ Per Client

COMPLIANCE WITH MIL STD 1567A:

Metcut is not a predetermined time system but a standard data system, based on selected material and machine speeds/feeds with primary emphasis on machining operations. The accuracy of standards developed using this system would be directly impacted by the manufacturing environment and the ability to perform at machine levels prescribed. As no statistical data was available for review, actual accuracy was unable to be verified. It should be noted that both the textbook and software approach to developing standards provides for an audit trail to the elemental level. Those basic requirements as specified in the MIL STD which were in question are as follows:

- All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level.

Those requirements which the system **does** meet are as follows:

- Documentation of an operations analysis.
- A record of standard practice or method followed when the standard was developed.
- A record of rating or leveling.
- A record of the standard time computation including allowances.

- A record of observed or predetermined time system time values used in determining the final standard time.

- Provision of an audit trail down to the elemental standard time level.

STRENGTHS & WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the METCUT™ predetermined time system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- System is easily learned and applied.

- The system's data on recommended speeds and feeds cover the latest in machining equipment, material, and process technology.

- Computerized application provides improved speed, accuracy and consistency of application, and enables the user to more easily modify estimates, perform mass updates, and develop and analyze "what-if" methods improvement scenarios.

- The formulas for calculating metal removal rate, horsepower, and time required are programmed into the computer; however, these formulas are available in the Machining Data Handbook.

SYSTEM USERS:

Based on data supplied by the system vendor, a breakdown of system users by manufacturing type is as follows:

- CUTDATA™

APPLICATION TYPE	NUMBER OF COMPANIES
CONTRACT MACHINE SHOP	11
EDUCATION/RESEARCH INSTITUTES	10
AEROSPACE	10
MACHINE TOOL	4
AUTOMOTIVE	4
GENERAL INDUSTRIAL MACHINE & EQUIPMENT	4
GENERAL COMPONENTS	4
TOOL, DIE, JIG & FIXTURES	2
FARM MACHINERY & EQUIPMENT	1
COMPONENT EQUIPMENT	1
SURGICAL APPARATUS	1
METAL CANS	1

- CUTTECH™

  CUTTECH™ has recently been installed in four industrial organizations.

REFERENCE SOURCE:

Metcut Research Associates, Inc.

EASE

CONTACT: Trevor McAlester, Owner/Author
COMPANY: EASE, Inc.
ADDRESS: 32221 Camino Capistrano, San Juan Capistrano, CA 92675
PHONE: (714) 493-1862

SYSTEM HISTORY:

The **EASE** system was developed during 1985/1986 by Mr. John Smith and Mr. Trevor McAlester.

SYSTEM DESCRIPTION:

EASE (Engineering Assembly Standards and Estimates) is a software package that utilizes MTM-2 to enable a user to develop the following:

- Work Standards
- Detailed Process Plans
- Manufacturing Costs
- Method Improvements

The EASE system allows the user to develop work standards in three ways:

- **MTM-2 Generator**: Utilizes Methods Time Measurement-2 (MTM-2) for elemental standard data development.

- **EASE Macros**: Standard Data Blocks built out of MTM-2 which provide the user with a more rapid method of element generation. Each Macro is backed up by an MTM-2 pattern.

- **User Form Elements**: These elements have their own user defined questions, variables and formula. Typical applications would be machining, welding, and any other process times dependent on more than one variable.

All three of these approaches can be used in combination to create a work standard. In addition, available user standard data can be used to develop work standards for an activity.

Each activity can hold up to 30 elements. The activities themselves are then grouped into logical Data Groups. Each Data Group can hold up to 30 activities, which means that an operation analysis can access up to 900 elements, plus direct input.

SYSTEM APPLICATION:

EASE is a computerized menu driven system. The elements of an activity are created utilizing the system's Element Generation Menu. The elements can be created from existing EASE macros or straight from MTM-2 data. The Create Element Menu contains a number of work element types (i.e., job preparation, handling, assembly, disassembly, clear, gauge, lubricate, tool use, input MTM-2, MTM and analysis summary).

A created element consists of all the macros chosen from the various menus and their frequencies, and any MTM-2 codes used in the analysis.

An activity description and standard is created using the Activity Menu. This menu allows the analyst to build up an activity by listing previously created elements of that activity.

The EASE system can be applied to either **short or long cycle jobs, and highly repetitive, with no variations, or non-repetitive, with variations.**

The EASE system software was developed specifically for the IBM PC and compatible computers. The system is designed to be as "user friendly" as possible, from both the systems and engineering points of view. The data base is structured in such a way as to allow the user to set up the data at whatever level is required, with element times ranging from Time Motion Units to Hours.

TRAINING/TECHNICAL ASSISTANCE:

The EASE system is self taught for users familiar with personal computers and work measurement. In the event that a user wishes to have training in both the use of the software and EASE Macros, the system vendor provides two to five days of on-site training which provides the user with a sufficient level of knowledge of the system. Certification in use of the EASE system is available through examination.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
EASE system (includes element generation, and process planning module)	$5,000.00
EASE system - material schedule and cost roll up modules.	$3,000.00
Additional system manuals (the system is supplied with two software manuals and two Macro manuals).	$50.00 per copy
EASE System Training	$600.00 per day

COMPLIANCE WITH MIL STD 1567A:

Because EASE is a software package which basically uses MTM-2 to develop the standard times, its ability to be in compliance with the MIL STD is strictly dependent upon the level of accuracy of MTM-2. For the accuracy level of MTM-2 refer to System Accuracy, or System Descriptions sections.

STRENGTHS AND WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the EASE software system. The comments listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- Computerized application provides improved speed, accuracy and consistency of application, and enables the user to more easily modify standards, perform mass updates, and develop and analyze "what-if" method improvement scenarios.

- System will accept and manipulate data developed utilizing work measurement systems or techniques other than MTM-2.

- Cannot be manually applied.

- Since the system has been used in industry for approximately 1.5 years, there is little basis for judgment as to the system's effectiveness.

SYSTEM USERS:

For a system which is relatively new, the EASE system has five users as follows:

- Assembly (2)
- Electrical (1)
- Machining/Fabrication (2)

REFERENCE SOURCE:

EASE, Inc.

CSD/AML

CONTACT: Ms. Doris Boudreau, Vice President
COMPANY: Rath and Strong, Inc.
ADDRESS: 21 Worthen Road, Lexington, MA 02173
PHONE: (617) 861-1700

SYSTEM HISTORY:

CSD (Computerized Standard Data) and **CSD/AML** (Advanced Machining Logic) are two software packages originally developed by Rath and Strong in the 1970s, redesigned in 1981 and enhanced in 1986. CSD is used for manual operations and AML is for calculating metal removal processes. The 4M predetermined time generator became available for CSD and CSD/AML in 1986.

SYSTEM DESCRIPTION:

CSD is a shop floor control software package which enables the user to incorporate any predetermined time system or standard data in developing **manual time standards.** If no specific predetermined time system or standard data is specified, CSD can be supplied with MTM's 4M system. Some of the features CSD provides are as follows:

- Operation Standards
- Routings
- Operation Instructions
- Operation Cost Estimates
- MRP Interface

AML is a software system that enables the user to establish **machine time standards** using their own machining data or data supplied with the software. Data supplied with AML is based on engineering data available to industries regarding metal removal. AML determines the number of cuts and the feeds and speeds required to optimize the horsepower used in a particular machining operation.

AML is interfaced with CSD, thereby incorporating machine standards into the operation standards and other information produced by CSD.

SYSTEM APPLICATION:

The application procedures for CSD and AML depend on the predetermined time system, standard data, and/or machining data that has been built into the systems.

Again, depending on the data system used, CSD/AML can be used for **short- or long-cycle jobs** that are **repetitive or non-repetitive, with or without variations.**

The CSD/AML software can be used on an IBM PC-XT, AT or compatible computers, the Data General minicomputers, and IBM mainframe computers.

TRAINING/TECHNICAL ASSISTANCE:

Training for the CSD and CSD/AML software system is self-paced as the software is menu-driven. When 4M is used with CSD, the analysts must attend the 4M training classes offered by Rath and Strong. Certification is by the MTM Association.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE	
	Personal or Micro Computer	Mainframe Computer
CSD(2)	$10,000	$25,000
CSD/AML(2)	30,000	60,000
CSD/4M(1)(2)	39,000	55,000
CSD/AML/4M(1)(2)	60,000	90,000

NOTES: (1) 4M training for up to seven individuals is included in the purchase.

(2) One day of training and/or technical assistance is included in the purchase.

COMPLIANCE WITH MIL STD 1567A:

Because CSD/AML is basically a software package which uses other systems to develop the standard times, its ability to be in compliance is strictly dependent upon the level of accuracy of the systems used. For the accuracy level of 4M refer to System Accuracy or System Descriptions sections.

STRENGTHS AND WEAKNESSES:

No references were provided by the system vendor; therefore, the system's strengths and weaknesses could not be discussed with an actual user.

SYSTEM USERS:

The CSD systems are currently being used in five companies representing a variety of industries.

REFERENCE SOURCE:

Rath and Strong

SUPERCAPES

CONTACT: Alan Sheffield, Marketing & Sales Manager
COMPANY: Systems Control
ADDRESS: Two Rockledge Center, Suite 750, 6701 Rockledge Drive
Bethesda, MD. 20817
PHONE: (301) 571-1000

SYSTEM HISTORY:

SUPERCAPES I and II are software packages developed in 1978-79 by Methods Workshop LTD. in England.

SYSTEM DESCRIPTION:

Supercapes I is a software package that enables the user to develop route cards, operation-standards, and method specifications using a personal computer or microcomputer. **Supercapes** II is a software package for mini-computers and is a multi-user management tool which addresses the following functions: estimating, costing, process planning, industrial engineering.

Both systems can be used in developing **manual and process time standards** and will accommodate any predetermined time system desired or elemental data developed from other study techniques. In addition, Systems Control has developed General Assembly Data (GAD) which is standard data based on MTM.

GAD data represent common motion sequences which occur in a light bench or repetitive assembly environment. Each GAD code has a known Mean and Standard Deviation thereby providing the basis for determining overall accuracy when a number of elements are combined together at different frequencies. Because GAD is standard data, it must be evaluated as to its accuracy in each specific application.

The system vendor states that backup data for the GAD code can theoretically be generated using any level of MTM, although current backup data is provided based on MTM Core Data. MTM Core Data is a permutation of MTM developed in the United Kingdom which has not yet been officially accepted by the International MTM Association. The system vendor is currently in the process of developing backup data based on MTM-2.

Supercapes I and II can also be used to develop **machine time standards** using the company's own machining data or based on engineering data available through other metal removal resources.

A summary of the types of data available for both Supercapes I and II is shown below:

- **Machining** - Turning, Drilling, Milling, Grinding, Boring, Gear Cutting
- **General Purpose** - Sawing, Shearing, Cutting, Binding, Rolling, Welding, Pressing, Punching, Heavy Fitting, Heat Treatment, and other processes or activities.
- **Manual** - Bench, Line, Sub and Final Assembly

SYSTEM APPLICATION:

Supercapes I and II are both menu driven; however, the actual method of application will depend upon the predetermined time system, standard data, and/or machining data that has been built into the systems.

Again, depending on the measurement system used, Supercapes I and II can be used for **short-** or **long-cycle** jobs that are **repetitive** or **non-repetitive with** or **without variations.**

When GAD is incorporated into Supercapes I and II, the user has a choice of application methods as follows:

- The user can enter the proper GAD codes, chosen from a data card of 30 codes, by following computer prompts. The computer then generates a methods analysis.

- The user can follow pre-programmed question and answer prompts from which the computer selects the proper GAD codes and then generates a methods analysis.

GAD was developed only for light bench or repetitive assembly operations.

Supercapes I software can be used on an IBM PC-XT or AT; and, Supercapes II can be used on Digital's MicroVax or Vax, and HP's 1000 or 3000 models.

TRAINING/TECHNICAL ASSISTANCE:

Training for Supercapes I and II is performed at the user's site and focuses on "hands-on" experience. The time frame for training varies as follows:

- Supercapes I - 3 to 5 weeks
- Supercapes II - 5 to 8 weeks

If an MTM system is used, the above-mentioned time frames assume the user is certified in the appropriate MTM system.

SYSTEM COSTS:

COST CATEGORY	LIST PRICE
Supercapes I	
Training	$ 15,000(1)
Software	$ 30,000(2)
Supercapes II	
Training	$ 25,000(1)
Software	$ 70,000(2)

NOTES: (1) Training costs listed are based on an average and may vary with each client.

(2) Software prices listed are based on an average for one location and will increase if more modules and/or locations are required.

COMPLIANCE WITH MIL STD 1567A:

Because Supercapes I and II are basically software packages which use other systems to develop the standard times, their ability to be in compliance is strictly dependent upon the level of accuracy of the systems used.

STRENGTHS & WEAKNESSES:

Strengths and weaknesses and/or constraints identified are based on discussions with users of the Supercapes software systems. The comments

listed below are based on these discussions and, while a broad range of industries were sampled, comments should not be considered universal and therefore may not be applicable to all manufacturing environments:

- The system vendor provides exceptional technical assistance and customizing capabilities.
- The system provides for using formulas and prints out detail showing how the formula was used.
- The system is user friendly.
- The system can be networked with other manufacturing or financial systems.
- The system provides detailed documentation of standards development.
- It is difficult to locate information in the manuals provided with the systems.
- There is limited storage space available on the PC version (theoretically 30,000 live route cards).

SYSTEM USERS:

Based on data supplied by the system vendor, a breakdown of system users, in the United States, by manufacturing type is as follows:

Application Type	Number of Companies
Manufacturing	8
Electronics	6
Aerospace	3
Other	2

In addition, Supercapes is being, or has been used within 82 companies in the United Kingdom and Europe.

REFERENCE SOURCE:

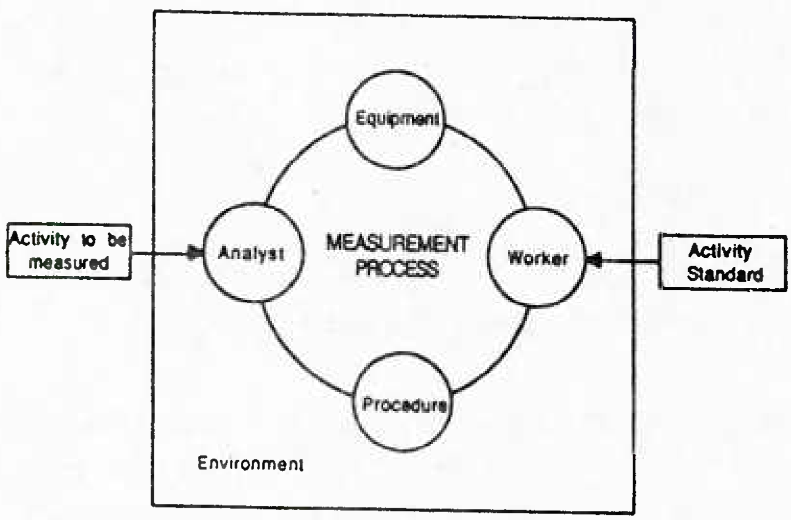
Systems Control

SYSTEM ACCURACY

Fundamental in evaluating any work measurement system is its ability to produce a work standard truly reflective of the activity in both work content and time requirement. Often the degree of accuracy obtainable is an economic decision, weighing the cost of higher accuracy against the economic benefit to be obtained from that accuracy level. However, this is a decision for general management. The engineer must work with whatever system is selected and, for that selected system, certain basic concepts must hold true.

Viewing work measurement as a production process, with the product being work standards, the process might be illustrated as in the following exhibit:

The Work Measurement Process (1)



(1) With modifications, from Karl F. Speitel, "Measurement Assurance", The Handbook of Industrial Engineering.

As the exhibit shows, a number of interrelated concepts must come together within the measurement process and each of these concepts introduces a potential for variability.

The activity to be measured comes into the measurement process and is subjected to one of a variety of measurement techniques (e.g., stopwatch, element charts, predetermined time system, standard data card), while being performed by a production worker. The operating environment can and does have a significant effect on the quality of the resulting standard, as does the skill of the analyst and the worker performing the activity.

In addition to the impact the process can have on the resultant standard, there are several other key concepts which become fundamental to the application of the work measurement process.

TRUE VALUE

This concept while easy to describe, can be very difficult to define in the measurement process. For example, process limitations can vary from one activity to another, or similar activities due to the criticality of the part being produced. Such variations can have a direct impact on setup, run, inspection, and process cycle time.

PRECISION

Within the measurement process, precision most frequently is tracked by the standard deviation reported in the element values.

This quantification of differences among repeated measurements of the same elemental activity indicates how far off the mark (from the "true value") our measured activity can be, when viewing only small samples of the data. A common term related to this concept is "repeatability," which expresses estimates of anticipated performance closeness to a given standard, over many tests.

BIAS

Bias, also called system error, refers to a characteristic of measurement systems, in which a result produced from the system varies from the true value by a consistent and predictable amount. For example, performance rating bias in time study is well-recognized - the tendency to rate workers consistently high or low - and can be neutralized without destroying the value of the

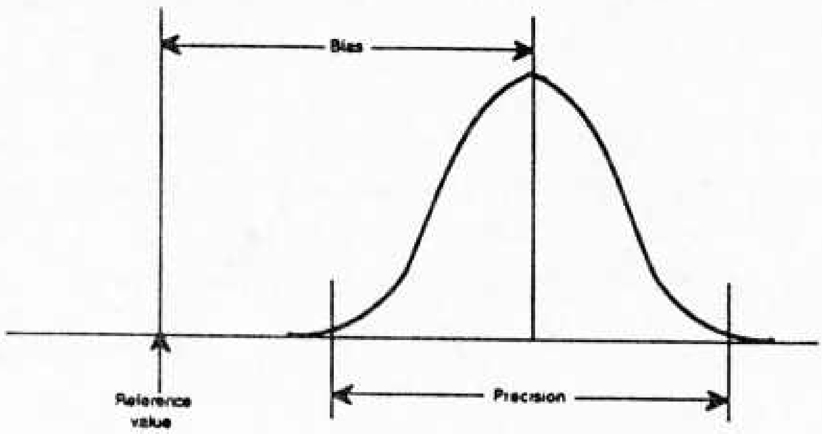
analysis. Bias, as long as it is consistent and measurable, can be "zeroed out" in the everyday application of a measurement system.

ACCURACY

Accuracy refers to the agreement of individual study values with an accepted true value, when the study method and the sample size of the study have been predetermined.

Distinctions among the above-defined terms must be clearly understood in order for a measurement system to receive an accurate assessment, when the engineer is searching for the most appropriate and usable tool. The following exhibit reflects the interrelationship of the terms True Value, Precision, Bias, and Accuracy:

The Accuracy Diagram (2)



(2) Ibid

In summary, bias indicates definable difference from the truth, precision indicates how close samples center on the truth (with bias), while accuracy measures the system's closeness to the truth.

SYSTEM APPLICATION

Overlooked many times during the evaluation of the total accuracy of a given predetermined time system is the applicators' ability to apply the system properly. While the system's inherent accuracy can be determined statistically, applicator error must be evaluated based on observation and/or experiences. Applicator accuracy will vary between individuals, depending on the amount of training and experience each posseses.

One may conclude that as a system becomes more defined it also becomes more accurate due to less deviations. While this may be true, the more selections and decision points required of the applicator can create more opportunity for applicator error.

In the majority of instances, the most frequent type of applicator error has been related to the ommission of required activites and/or motions or the inclusion of a motion and/or activity that does not occur during the performance of a given operation.

Although very little research has been done in this area, applicator error influences the total accuracy of a system as much or more than the system itself. Through proper training and application experience, this opportunity for applicator error can be significatntly reduced.

TRACEABILITY

Another important concept to be considered when selecting a measurement systems is traceability. Traceability exists when evidence shows the system to reproduce measurement results for which the measurable uncertainty to some standard is quantified (typically ± 5% error, 95% confidence interval).

Since the time elements used by many of the systems presented in this reference guide can be traced to MTM-1 and since numerous systems compare their analysis results to similar analyses by using MTM-1, it was necessary to evaluate both the level of accuracy of the MTM-1 predetermined time system and

the accumulated accuracy of those systems which used MTM-1 as their reference base. The following paragraphs describe in more detail the approach used, and individual system accuracy and analysis.

GENERAL SYSTEM ACCURACY

During the evaluation of individual system accuracy for each of the predetermined time systems presented in the reference guide, a question was raised concerning "accumulated system accuracy." As many of the systems reviewed compared themselves to MTM-1 analyses, accumulated accuracy began to play a key role in validating the system's ability to meet MIL STD 1567A. It is generally accepted that MTM-1 is the most accurate system, and one which claims an accuracy level of ± 5% at a 95% confidence level. However, if a system is found to be within ±5% of MTM-1, what is the resultant accuracy level of the second system?

To be in compliance with MIL STD 1567A, a system's accuracy level must be at least ±10% at a 90% confidence level. It was therefore important to verify that reviewed systems met this MIL STD 1567A requirement. To answer the question of "accumulated system accuracy," for each of the predetermined systems reviewed, a simulation effort was performed as follows:

Accumulated accuracy equation:

$$\delta = \sqrt{.05^{2} + (x)^{2}}$$

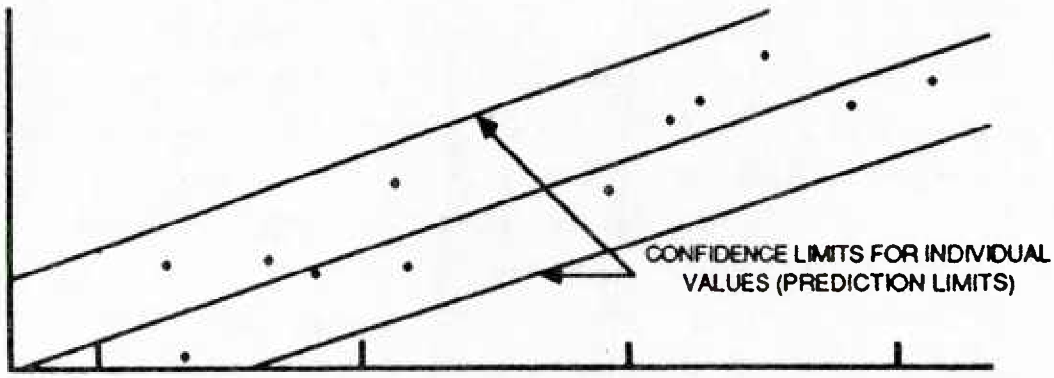
where δ = accumulated accuracy

.05 = absolute variance of MTM-1

x = absolute variance (in %) of the reviewed system

A simulation was performed which randomly generated 1000 numbers positioned around a theoretic norm, with a total system variance of ±5% at a 95% confidence level, as shown in the following illustration:

GRAPH



RANDOM POINT VALUES WITH
VAR = ±5% OF NORM.

Having selected these 1000 point values, several scenarios were then developed to show the net effect of a secondary accuracy level of from 1% to 8%, on top of the base system's ±5%, to arrive at the accumulated accuracy.

Random numbers were generated to develop secondary point values around the primary point values, with fixed variances as desired.

In total, 10,000 iterations were performed, with net variances accumulated for each accuracy percentage. The resulting accumulated accuracy levels were developed as shown in the following table:

Table 1.0 Accumulated System Accuracy

System Accuracy Variance	Net Accumulated System Accuracy
1%	5.10%
2%	5.38%
3%	5.83%
4%	6.40%
5%	7.07%
6%	7.81%
7%	8.60%
8%	9.43%
9%	10.30%

Based on ±5% at a 95% confidence level.

Using the above table, accuracy levels for those systems comparing themselves to MTM-1 were developed with the results shown in Table 1A. The evaluation process performed is described in detail in the following paragraphs.

Table 1A Accumulated System Accuracy by System

System	System Accuracy Variance to MTM-1	Net Accumulated System Accuracy
MTM-2	0.23%	5.0%
MTM-3	0.36%	5.0%
MTM-MEK	3.20%	5.94%
MTM-UAS	1.26%	5.16%
MTM-TE	1.77%	5.30%
MTS	5.08%	7.12%
MANPRO	6.68%	8.34%
CUE	2.62	5.64%
MSD	0.75%	5.06%
UNIVEL	0.42%	5.02%
MODAPTS	5.90%	7.73%
WORK-FACTOR	18.75%	19.40%

Based on ±5% at 95% confidence level.

INDIVIDUAL SYSTEM ACCURACY

MTM-1

As the predetermined time system against which most other measurement systems are compared, MTM-1 was evaluated based on several studies. The first study reviewed was performed by W. D. Brinckloe and M. T. Coughlin. The results were published in "Precision Analysis of MTM-1 and MOST®." The study analyzed the following basic motions: Reach, Move, Apply Pressure, Grasp, Position, Release, Loosen, and Body Movement. These motions were studied for Production Type B (medium-heavy assembly work) and Production Type C (light assembly work) groups, which constituted over 51% of the total TMU times of the study data published in "Frequency of Occurrence of Basic MTM Motions" by Ulf Aberg of the Swedish MTM Association Research Committee.

In reviewing the study it was found that the variance in Brinckloe's calculations consisted of two parts: (1) variance for the total range of the data card value (based on the rectangular distribution), and (2) variance arising from a nonsymmetrical data card value (i.e., the data card value does not occur at the mid-point of the range). The formula used is as follows:

$$\sigma^2_{\text{distance}} = \sigma^2_{\text{rectangular}} + \sigma^2_{\text{nonsymmetry}}$$

$$= \frac{(U - L)^2}{48} + \frac{(U + L - 2 \times D)^2}{16}$$

where U = upper range value
L = lower range value
D = data range value

To compute the variance for Reach, four values (R3B, R26B, R3C, and R26C) were considered, representing 89.5% of all Reach motions. The values selected for Move were M3B5, M26B40, M3C5 and M26C40. (The variance for case and weight in this category was also computed and added to the total.) The variance for Apply Pressure is zero, since one of two correct values are selected and do not represent a range of values. The predominant motions for Grasp were G1A, G1B and G4. In analyzing Position, the most frequently observed values were P1SE, P1SSE, P1NSE, P2SE, P2SSE, and P2NSE. The variance for Release had a

single value while the variance for Disengage included three representative selections: D1E, D2E and D2D. The variance for Body Motion consisted of "walk" and "turn body."

Using the formula stated above and weighting the variances by the frequency of occurrence from Aberg's studies, Brinckloe obtained the results presented in the following table:

Table 2.0 Weighted Variance of MTM-1 (Prod. Types B and C)

MOTION	VARIANCE	% FREQUENCY	EXPECTED VARIANCE
Reach	0.465	12.8	0.060
Move	1.547	29.5	0.456
Pressure	0	5.9	0
Grasp	0.320	23.8	0.076
Position	36.726	12.5	4.591
Release	0.333	11.4	0.038
Disengage	18.599	1.7	0.399
Body Motion	19.739	2.4	0.474
		100.0	
Estimated MTM-1 Variance		=	6.094 TMU^2

This weighting procedure was then used to obtain an average TMU value for each motion category. A check of these calculations was performed and is presented in Table 3.0 on the following pages. The TMU value for each motion was listed and checked against the MTM-1 data card value. The calculations follow those used to determine the variance shown in the Brinckloe study. The results obtained were the same as tabulated by Brinckloe, with the exception of Body Motion. Using the proportions of 25.8% for walk and 55.1% for turn, the check procedure gave a TMU value of 23.78, while Brinckloe's value was listed as 65.38. Since Brinckloe did not list his calculations for weighted TMU values, it was assumed that he factored in other values listed on the MTM-1 data card.

Using the results of the weighted TMU calculations, Brinckloe then computed the expected balance time for each motion. A check on the balance time calculations (see Table 4.0, 5.0, 6.0) gave the same results except for Disengage, which was 3679 TMU versus 5101 TMU for Brinckloe's value. Applying the frequency of occurrence from Aberg's studies to each balance time, the estimated MTM-1 balance time is 697 TMU.

CONCLUSION:

As a system developed from motion film analysis, system error can arise from the use of a single value to represent a range of possible values. Based on the review of Brinckloe's variance calculations, the system error for MTM-1 was found to be ± 5% at the 95% confidence level. In summary, for operations of a length of 700 TMUs or longer, MTM-1 will reflect a system accuracy of ±5% at a 95% confidence level.

TABLE 3
WEIGHTED TMU CHECK
BALANCE TIME CALCULATION FOR 95% ± 5%

1. Reach

R3B	5.3
R26B	22.9
R3C	7.3
R26C	23.9

Avg:

$$\frac{61.3}{89.5}\left(\frac{5.3 + 22.9}{2}\right) + \frac{7.3 + 23.9}{2}\left(\frac{28.2}{89.5}\right) = 9.657 + 4.915 = \underline{\underline{14.572}}$$

2. **Move**

M3B5	8.24
M26B40	45.692
M3C5	9.302
M26C40	53.612

$$\frac{8.24 + 45.692}{2}\left(\frac{53.3}{95.7}\right) + \frac{9.302 + 53.612}{2}\left(\frac{42.4}{95.7}\right) =$$

$$15.019 + 13.937 = 28.956 \qquad \Rightarrow \quad 29.01$$

3. **Pressure**

APA	10.6
APB	16.2

$$\frac{10.6 + 16.2}{2} = \underline{\underline{13.40}}$$

4. **Grasp**

G1A	2
G1B	3.5
G4A	7.3

$$\frac{27.5}{45.65}(7.3) + \frac{(2 + 3.5)}{2}\left(\frac{18.15}{45.65}\right) = 4.398 + 1.093 = \underline{\underline{5.491}}$$

5. **Position**

P1SE	5.6
P1SSE	9.1
P1NSE	10.4
P2SE	16.2
P2SSE	19.7
P2NSE	21.0

$$\text{PSE}\ \frac{27.9}{94.55}(5.6) + \frac{66.65}{94.55}(16.2) = 1.652 + 11.42 = 13.072$$

$$\text{PSSE}\ \frac{27.9}{94.55}(9.1) + \frac{66.65}{94.55}(19.7) = 2.685 + 13.887 = 16.572$$

$$\text{PNSE}\ \frac{27.9}{94.55}(10.4) + \frac{66.65}{94.55}(21.0) = 3.069 + 14.803 = 17.872$$

$$13.072(.641) + 16.572(.267) + 17.872(.092) =$$

$$8.379 + 4.425 + 1.644 = \underline{14.448}$$

6. **Release**

$$\frac{(2 - 0)}{2} = \underline{\underline{1}}$$

7. **Disengage**

D1E	4.0
D2E	7.5
D2D	11.8

$$(4 + 7.5 + 11.8)/3 = \underline{\underline{7.767}}$$

8. Body Motion

$$\text{Walk } 15 \times \frac{25.8}{80.9} = 4.784$$

$$\text{Turn } (37.2 + 18.6)/2 = 27.9 \times \frac{55.1}{80.9} = 19$$

$$19 + 4.784 = 23.784$$

TABLE 4
BALANCE TIME CHECK

1. Reach

$\overline{x} = 14.572$

$\sigma^2 = .465$ $\sigma = .682$

$1.96\,\sigma = 1.337$

$\pm r = \frac{1.337}{14.572} = .092$

$n = \left(\frac{.033}{.05}\right)^2 = 3.386 \times 14.572 = 49.34$ vs. 49.60

2. Move

$\overline{x} = 29.01$

$\sigma^2 = 1.547$ $\sigma = 1.244$

$1.96\,\sigma = 2.438$

$\pm r = \frac{2.438}{29.01} = .084$

$n = \left(\frac{.084}{.05}\right)^2 = 2.822 \times 29.01 = \text{Bal Time} = 81.866$ vs. 81.93

3. Pressure

$\overline{x} = 13.4$

$\sigma^2 = 0$ $\sigma = 0$

Bal Time $= 0 \times 13.4 = 0$

4. **Grasp**

$\bar{x} = 5.49$

$\sigma^2 = .32 \qquad \sigma = .566$

$1.96\,\sigma = 1.109$

$\pm r = \frac{1.109}{5.49} = .202$

$n = \left(\frac{.202}{.05}\right)^2 = 16.322 \times 5.49 = 89.61 \quad \text{vs.} \quad 87.71$

5. **Position**

$\bar{x} = 14.44$

$\sigma^2 = 36.726 \qquad \sigma = 6.06$

$1.96\,\sigma = 11.8776$

$\pm r = \frac{11.8776}{14.44} = .823$

$n = \left(\frac{.823}{.05}\right)^2 = 270.932 \times 14.44 = 3912.23 \quad \text{vs.} \quad 3917.44$

6. **Release**

$\bar{x} = 1$

$\sigma^2 = .333 \qquad \sigma = .577$

$1.96\,\sigma = 1.131$

$\pm r = \frac{1.131}{1} = 1.131$

$n = \left(\frac{1.131}{.05}\right)^2 = 511.66 \times 1 = 511.66 \quad \text{vs.} \quad 511.49$

7. <u>Disengage</u>

$\bar{x} = 7.77$

$\sigma^2 = 18.599 \qquad \sigma = 4.313$

NOTE: would have to equal 5.079 to get Brinckloe's answer.

$1.96\sigma = 8.453$

$\pm r = \frac{8.453}{7.77} = 1.088$

$n = \left(\frac{1.088}{.05}\right)^2 = 473.5 \times 7.77 = 3679.1 \quad \text{vs.} \quad 5101.5$

8. <u>Body Motion</u>

$\bar{x} = 65.38$

$\sigma^2 = 19.739 \qquad \sigma = 4.443 \qquad 1.96\sigma = 8.70$

$\pm r = \frac{8.70}{65.38} = .133$

$n = \left(\frac{.133}{.05}\right)^2 = 7.075 \times 65.38 = 462.56 \quad \text{vs.} \quad 465.02$

TABLE 5
BALANCE TIME CHECK

	EXPECTED BALANCE TIME	FREQUENCY	BAL. TIME
Reach	49.34	12.8%	6.32
Move	81.87	29.5	24.15
Pressure	0	5.9	0
Grasp	89.61	23.8	21.33
Position	3912.23	12.5	489.03
Release	511.66	11.4	58.33
Disengage	3679.1	1.7	62.54
Body Motion	462.56	2.4	11.10

Calculated MTM-1 Balance Time	672.80	TMU
Brinckloe's calculation	697.28	TMU
MTM Advertised Balance Time	624	TMU

° NOTE:

Difference in TMU's between calculated, Brinckloe, and/or MTM advertised could be due to discrepancy in the DISENGAGE calculation.

TABLE 6
BALANCE TIME CALCULATION FOR 90% $\pm$ 10%

$z = 1.645$

1. **Reach**

$\bar{x} = 14.572$

$\sigma = .682$

$1.645\,\sigma = 1.122$

$\pm r = \frac{1.122}{14.572} = .077$

$n = \left(\frac{.077}{.10}\right)^2 = .593 \times 14.572 = 8.64$

2. **Move**

$\bar{x} = 29.01$

$\sigma = 1.244 \qquad 1.645\,\sigma = 2.046$

$\pm r = \frac{2.046}{29.01} = .0705$

$n = \left(\frac{.0705}{.10}\right)^2 = .497 \times 29.01 = 14.42$

3. **Pressure**

Bal Time = 0

4. **Grasp**

$\bar{x} = 5.49$

$\sigma = .566 \qquad 1.645\,\sigma = .931$

$$\pm r = \frac{.931}{5.49} = .170$$

$$n = \left(\frac{.170}{.10}\right)^2 = 2.89 \times 5.49 = 15.87$$

5. **Position**

$\bar{x} = 14.44$

$\sigma = 6.06 \qquad 1.645\,\sigma = 9.97$

$$\pm r = \frac{9.97}{14.44} = .690$$

$$n = \left(\frac{.690}{.10}\right)^2 = 47.61 \times 14.44 = 687.49$$

6. **Release**

$\bar{x} = 1$

$\sigma = .577 \qquad 1.645\,\sigma = .95$

$$\pm r = \frac{.95}{1} = .95$$

$$n = \left(\frac{.95}{.10}\right)^2 = 90.25 \times 1 = 90.25$$

7. **Disengage**

$\overline{x} = 7.77$

$\sigma = 4.313 \qquad 1.645\,\sigma = 7.095$

$$\pm r = \frac{7.095}{7.77} = .913$$

$$n = \left(\frac{.913}{.10}\right)^2 = 83.36 \times 7.77 = 647.71$$

8. **Body Motion**

$\overline{x} = 65.38$

$\sigma = 4.443 \qquad 1.645\,\sigma = 7.31$

$$\pm r = \frac{7.31}{65.38} = .112$$

$$n = \left(\frac{.112}{.10}\right)^2 = 1.25 \times 65.38 = 81.73$$

TABLE 7
BALANCE TIME CALCULATION FOR 90%, ± 10%

	BALANCE TIME	FREQUENCY	EXPECTED BAL. TIME
Reach	8.64	12.8%	1.11
Move	14.42	29.5	4.25
Pressure	0	5.9	0
Grasp	15.87	23.8	3.78
Position	687.49	12.5	85.94
Release	90.25	11.4	10.29
Disengage	647.71	1.7	11.01
Body Motion	81.73	2.4	1.96

Estimated MTM-1 Balance Time at 90% = 118.34 TMU

In addition to the above study, a review of predetermined time systems conducted in 1950 by Cornell University was also analyzed.

The purpose of the study was to address the "validity and applicability of elemental motion time standards."

New films, calibrated to 1000 frames per minute, were taken on operations ranging from small assembly and riveting operations to machine-handling operations for a variety of industries, represented by eight different companies. The films were then analyzed and compared to MTM-1 elements. The actual time for each element was determined from the frame count. These actual times were then leveled to determine the time for a normal operator. Results for Reach - Case B, and Move - Case C, are shown in the table on the following page.

TABLE 8

DISTANCE IN INCHES	REACH - CASE B ACTUAL TIME	REACH - CASE B MTM-1 TIME	MOVE - CASE C ACTUAL TIME	MOVE - CASE C MTM-1 TIME
1	1.9	2.1	2.2	1.7
2	3.9	4.3	4.1	4.2
3	5.4	5.9	5.6	5.7
4	6.6	7.1	6.9	7.3
5	7.6	7.8	8.1	8.7
6	8.5	8.6	9.1	9.7
7	9.3	9.3	10.1	10.8
8	10.1	10.1	11.0	11.8
9	10.8	10.8	12.0	12.7
10	11.6	11.6	12.9	13.5
12	13.0	12.9	14.7	15.2
14	14.5	14.4	16.6	16.8
16	16.0	15.8	18.5	18.7
18	17.5	17.2	20.3	20.4
20	19.0	18.6	22.2	22.1
22	20.5	20.1	24.1	23.8
24	22.0	21.5	26.0	25.5
26	23.5	22.9	27.9	27.3
28	24.9	24.4	29.7	29.0
30	26.4	25.8	31.6	30.7

Total study time produced 1606.8 TMUs versus 1621.2 TMUs for the MTM-1 data values. This gave a difference of 14.4 TMUs or 0.9%.

From this study, the Cornell University team concluded that the reproduction of MTM-1 values by its independent test was very significant. Its practical application is that work elements can be defined "in terms of fundamental elements of motion common to a wide range of industrial activity and the establishment of time for these elements which are reproducible within smaller limits than those normal to current time study practice."

MTM-2

MTM-2 groups sets of motions from MTM-1 to obtain its values. In the paper "Precision Analysis of MTM-2" by W. D. Brinckloe, the design of the nine MTM-2 motion categories was reviewed. These categories are Get, Put, Apply Pressure, Regrasp, Eye Action, Crank, Step, Foot Motion, and Bend and Arise. After analyzing the derivation of MTM-2 from MTM-1, Brinckloe calculated the variance and balance time for MTM-2. The frequency data used in Brinckloe's study was drawn from the report "MTM-2 Project" by the International MTM Directorate.

The first MTM-2 motion category, Get, incorporates three MTM-1 motion categories — Grasp, Reach and Release. There are three cases for Get: (1) A - no grasping required, (2) B - single grasping motion, and (3) C - all other motions. Get Case A (GA) corresponds to G5 in MTM-1, Get Case B (GB) corresponds to G1A in MTM-1, and Get Case C (GC) corresponds to all remaining Grasp motions in MTM-1. The grasp value for GA is 0 TMU; the grasp value for GB is 2 TMU; and the grasp value for GC is 8.95 TMU, which is a weighted average of the MTM-1 grasp values (G1B, G1C1, G1C2, G1C3, G4A, G4B, and G4C). For the Reach component of Get, a weighted value based on the observed frequencies of occurrence was calculated for the three cases (GA, GB, and GC) from the MTM-1 Reach categories of R-A, R-B, and R-C. Finally, for the Release component of Get, a statistical analysis revealed 95% of all G1A and all other Grasps were followed by RL1. This corresponds to an applied value of 0 TMU to GA, and a value of 2 TMU to GB and to GC. The TMU values for the components Grasp, Reach and Release were summed for each Get case. Then the number of distance classes was calculated for MTM-2, resulting in five. The optimum distances for the five classes were calculated and rounded to 2", 6", 12", 18", and 32". The resulting values for the three cases of Get at these five distances, are shown in Table 9.0 below.

Table 9.0: MTM-2 Values of Get

RANGE	CODE	GA	GB	GC
Up to 2"	2	3	7	14
Over 2" - 6"	6	6	10	19
Over 6" - 12"	12	9	14	23
Over 12" - 18"	18	13	18	27
Over 18"	32	17	23	32

The second MTM-2 category, Put, was constructed similarly to Get. Put is derived from the MTM-1 motions, Move and Position. Three cases apply to Put: (1) A - no correcting action (continuous movement), (2) B - single correcting action, and (3) C - all other motions. Weighted averages were built up from Move and Position and were applied to the three categories. The same five distance ranges used for Get were selected for Put. The results are shown in Table 10.0 below.

Table 10.0: MTM-2 Values of Put

RANGE	CODE	GA	GB	GC
Up to 2"	2	3	10	21
Over 2" - 6"	6	6	15	26
Over 6" - 12"	12	11	19	30
Over 12" - 18"	18	15	24	36
Over 18"	32	20	30	41

Get and Put each also have a weight factor. For Get, the value is 1 TMU per 2 pounds; for Put, the value is 1 TMU per 10 pounds.

The values for the seven remaining MTM-2 categories were much simpler to derive. For Apply Pressure, there are two values in MTM-1: (1) 10.6 and (2) 16.2. Using the observed frequency values of 43% and 57%, respectively, the weighted average is 13.79 TMU in the MTM-2 table. Regrasp has a single value in MTM-1, 5.6 TMU, rounded to 6 TMU in the MTM-2 table. For Eye Motion, the

MTM-2 value of 7 TMU was taken from the MTM-1 allowance for Eye Focus (7.3 TMU) and the multiplier for Eye Travel (15.2 TMU for each radian of angular travel). The MTM-2 value of 7 TMU corresponds to a 26^{o} rotation for Eye Travel in MTM-1.

The MTM-1 values for Crank include the following factors:

a. Both static and dynamic components, as in Move.
b. Distance covered (cranking diameter and number of revolutions).
c. Whether continuous or intermittent cranking.

To arrive at a single value for MTM-2, the designers applied the observed frequencies to TMU values of MTM-1 intermittent and continuous crank situations between 12 and 30 centimeters. The result was a value of 15 TMU per revolution for MTM-2.

For the MTM-2 category Step, the value of 18 TMU was obtained from the weighted values of the MTM-1 motions Side Step, Turn, and Walk. The time value for Foot Motion is 8.5 TMU in MTM-1, rounded to 9 TMU in the MTM-2 table. The last MTM-2 category, Bend and Arise, is the sum of two MTM-1 motions: Bend, Stoop and Kneel (29.0 TMU), and Arise (31.9 TMU). The value was rounded to 61 TMU for MTM-2.

After analyzing the construction of the MTM-2 table, Brinckloe calculated the system variance. The error in MTM-2 has two parts: (1) that involved in using one MTM-2 value to represent several MTM-1 values, and (2) that involved because of the error of MTM-1 in itself. Accordingly, the calculations for the variance of Get and Put were quite complex since each was derived from multiple MTM-1 categories. For Get, recall that the MTM-1 categories were Grasp, Reach and Release. In cases GA and GB, the grasp values corresponded to a single point value in MTM-1, so there is no variance. In case GC, however, seven MTM-1 values were combined into the MTM-2 value so that variance of these ranges was calculated. The Reach component for cases GA and GB combined two values - RA and RB - into each case. Brinckloe calculated the variance for this and also the variance from the range of values. Case GC for Reach involves the variance from the range only since it was constructed

singularly from RC. The Release component was taken from a single point value and therefore has no variance. The variances by case from the MTM-1 components were calculated and then weighted to obtain the value 6.218 TMU^2 for the variance of Get.

The variance of Put was calculated in the manner used for Get. The variance by case was weighted to obtain the value 20.591 TMU^2. For Apply Pressure, the variance was that of the MTM-1 values (10.6 and 16.2) about the MTM-2 value (14); the result was 7.73 TMU^2. The variances of Regrasp and Eye Motion consisted of the rounding error. The variance of Crank was obtained from the weighted values for the intermittent and continuous MTM-1 variances. Step had a variance due to the MTM-1 values around the MTM-2 values. The variances of Foot Motion, and Bend and Arise, incurred through rounding are considered negligible.

To compute the balance time of MTM-2, Brinckloe determined the weighted average motion length from the values in the MTM-2 table.

Applying a weighted average variance of 11.762 TMU^2 at the 95% confidence level, the result was a balance time of 1473 TMU.

CONCLUSION

Based on the review of the Brinckloe study, it was concluded that the calculations used to develop the MTM-2 TMU values from MTM-1 data were valid. Furthermore, the calculations of variance and balance time were determined to be correct, based upon the data presented. In summary, for operations of 1473 TMU or longer, MTM-2 will reflect a system accuracy of ±5% at a 95% confidence level.

In addition to the above study, several other studies were analyzed. The first of these was the paper, "Derivation of MTM-2 Time Standards," by the MTM Association, which presented the calculations used in designing MTM-2. The formulas used to calculate the MTM-2 values were:

Get A = fRA + fRB + G5 + RL2

Get B = fRA + fRB + G1A + RL1

Get C = RC + G* + RL1

(where f is the frequency of occurrence found for each case and * represents the remaining MTM-1 Grasp cases). The MTM-1 values were summed and then rounded to the nearest whole number to produce the values shown in Table 11.

Table 11: MTM-2 Values for Get

Range (cm)	GA	GB	GC
5	3	7	14
15	6	10	19
30	9	14	23
45	13	18	27
80	17	23	32

The Put motion is derived from the MTM-1 motions, Move and Position. The formulas used to calculate the MTM-2 values were:

Put A = fM-A + fM-B + fM-C

Put B = M-C + P1

Put C = M-C + P2

(where f is the frequency of occurrence of each motion; P1 is the weighted average of P1SE and P1SSE; and P2 is the weighted average of P1SD, P1SSD, P1NSE, P1NSD, P2SE, P2SD, P2SSE, P2SSD, P2NSE and P2NSD). The same five distances of Get are used for Put, and Table 12 shows the resulting values.

Table 12: MTM-2 Values of Put

Range (cm)	GA	GB	GC
5	3	10	21
15	6	15	26
30	11	19	30
45	15	24	36
80	20	30	41

The Regrasp motion has the value of 6 TMU, rounded from the MTM-1 value of 5.6 TMU. The Apply Force motion is a weighted average of the two MTM-1 values, 16.2 and 10.6, rounded to 14 TMU. Eye Motion is the rounded value of the MTM-1 value for Eye Focus, 7.3 TMU rounded to 7 TMU. The MTM-1 value for Foot Motion, 8.5 TMU, is rounded to 9 TMU for MTM-2. The motions that made up Step were Side Step, Turn, and Walk from MTM-1; the formula used (showing the weighting factors) was:

Step = .07 SS-C1 + .03 SS-C2 + .40 TB1 + .20 TB2 + .23 W-P + .06 W-PO

with the resulting value of 17.6 rounded to 18 TMU. The Bend motion is the rounded sum of the MTM-1 motions, Bend, Stoop and Kneel (29.0 TMU), and Arise (31.9 TMU). The last motion for MTM-2, Crank, is 15 TMU, obtained from an analysis of cranking motions in MTM-1.

The second study, which compared the accuracy of MTM-2 to MTM-1 and was entitled, "The MTM-2 Project" by the International MTM Directorate, was also reviewed. During the study, various operations were chosen at random and two MTM technicians analyzed the tasks, with the results shown in Table 13.

Evaluation as to the accuracy of MTM-2 was based on a sample of seven activities. The average length of the operations studied was 6856 TMU for MTM-1 and 6840 TMU for MTM-2. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of MTM-2 will not deviate greater than ±5% when compared to MTM-1 was tested (see Table 13).

A confidence level of 95% was used to obtain the critical region of $T < -2.447$ and $T > 2.447$, with 6 degrees of freedom.

Calculations for the "t" test gave a value of -0.13 which fell within the range $-2.447 < t < 2.447$. Therefore, from the data provided, it can be concluded that the accuracy of MTM-2 does not deviate greater than ±5% at the 95% confidence level, when compared to MTM-1.

The values of the studies provided are shown in Table 14. The deviation and percent deviation for each study was calculated and summed.

Table 13: MTM-2 - "T" Test

$H_0: \mu_D = d_0$

$H_1: \mu_D \neq d_0$

$\alpha = 0.05$

$\nu = 6$

$\Sigma d = -109$

$\Sigma d^2 = 586,815$

Critical region:

$T_{\alpha/2,6}$ $\quad T_{.025} < -2.447 \quad T_{.025} > 2.447$

"t" test statistic:

$t = \overline{D} - d_0 / S_d/\sqrt{n}$

$\overline{D} = \Sigma d/n = -109/7 = -15.57$

$S^2_d = n\Sigma d^2 - (\Sigma d)^2/n(n-1)$

$= 7(586,815) - (-109)^2/7(6)$

$= 4,107,705 - 11,881/42$

$= 97,519.6$

$S_d = \sqrt{97,519.6} = 312.3$

$t = -15.57-0 / 312.3/\sqrt{n}$

$= -0.13$

$-2.447 < -0.13 < 2.447$

Table 14: MTM-2 vs. MTM-1

ACTIVITY	MTM-1	MTM-2	DEVIATION	% DEVIATION
1	6737	6863	126	1.9
2	4932	4803	-129	-2.6
3	8713	8637	- 76	-0.9
4	7583	6959	-624	-8.2
5	2734	2895	161	5.9
6	12055	12412	357	3.0
7	5236	5312	76	1.5
TOTAL	47990	47881	-109	.23

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be .23%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±5.0% at a 95% confidence level.

MTM-3

MTM-3 is a third-level system which was developed to have an application time approximately seven times as fast as MTM-1.

The accuracy of MTM-3 was documented in the paper, "Accuracy Comparisons of MTM-1, GPD, MTM-2, MTM-3 and the AMAS Systems" by Hancock, Foulke, and Miller. This paper presented the combined results of two studies and gave an estimated system variance of 8.219 TMU^2 and standard deviation of 2.867 TMU for MTM-3. The data was from the following studies: "Summary of U.S./Canada Experiments on the Precision of GPD and MTM-3" by Foulke and Hancock, and "The MTM-3 Project Report" by Magnusson and Silverfrost. Results of the two studies are shown below.

Table 15: MTM-3 Variance Results

	STUDY 1	STUDY 2
TMU Analyzed	9,019	66,683
System Variance	5.4913	4.490
Applicator Variance	5.675	3.1366
Total Variance Calculated	11.410	7.872
<u>WEIGHTED COMPONENTS:</u>		
System Variance	4.609	
Applicator Variance	3.364	
Combined Weighted Estimates	8.219	

In a second study, a summary of the derivation of the MTM-3 table was presented. The study was conducted by the International MTM Directorate and entitled "The MTM-3 Project Technical Report."

MTM-3 consists of four motions: Handle, Transport, Step and Bend. Handle and Transport each have two cases, A and B, and two distances, 6" and >6", for a total of 10 values for MTM-3. Handle-Case A is a weighted average of the MTM-1 motions of Reach, Grasp, Move, Apply Pressure, Release and Disengage. Handle-Case B is a weighted average of the MTM-1 motions of Reach, Grasp, Move, Position, Release, and Apply Pressure. Table 16 summarizes the findings of the Handle calculations.

Table 16: **MTM-3 Values for Handle Derivation**

CASE	DISTANCE	TOTAL SAMPLE TMU	NO. OF OBS.	AVG. TMU	VARIANCE (MTM-1)	VARIANCE (MTM-3)	VARIANCE (TOTAL)	BALANCE TIME
A	≤6"	13601.9	755	18	5.11	91.45	96.56	8300
	>6"	13663.6	404	34	7.23	91.48	98.71	4500
B	≤6"	4254.0	125	34	42.87	56.36	99.23	4500
	>6"	8677.7	182	48	39.81	127.31	167.12	5400

The Transport-Case A motions were derived from the MTM-1 motions of Move, Apply Pressure, Grasp, Turn, Eye Focus, and Disengage. For Transport-Case B, the MTM-1 motions used were Move, Position, Apply Pressure, G2 (Grasp) and Release. Table 17 shows the results of the Transport calculations.

Table 17: **MTM-3 Values for Transport Derivation**

CASE	DISTANCE	TOTAL SAMPLE TMU	NO. OF OBS.	AVG. TMU	VARIANCE (MTM-1)	VARIANCE (MTM-3)	VARIANCE (TOTAL)	BALANCE TIME
A	≤6"	10416.1	1546	7	2.03	30.58	32.61	7200
	>6"	15781.5	970	16	2.36	43.54	45.90	4400
B	≤6"	8194.2	395	21	42.30	59.62	101.92	7500
	>6"	3787.6	131	29	28.35	73.78	102.13	5400

The variances for Handle and Transport are shown as the sum of the variance contributed by the MTM-1 and MTM-3 components. The balance time calculations are based upon a 5% accuracy level at 95% confidence. A check on these calculations is shown in Table 18.

The two remaining motions, Step and Bend, are the same as that found in MTM-2, so the derivation was not reviewed again. Evaluation as to the accuracy of MTM-3 was based on sample data provided by the system vendor in which eight samples of MTM-3 values were compared to MTM-1 values. The average length of the operations studied was 8305 TMU for MTM-1 and 8335 TMU for MTM-3. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of MTM-3 will not deviate greater than ±5% when compared to MTM-1 was tested. (See Table 19.)

Table 18: Balance Time Check Calculations

$$\text{Balance time} = \left(\frac{r}{R}\right)^2 \times \text{Avg. motion time}$$

R = 0.05 = desired accuracy of 5%

$$r = \frac{z\sigma}{\text{Avg. TMU}}$$ where Z = 1.96 for 95% confidence level, σ = deviation

<u>HANDLE</u>

1. HA6:

$$r = \frac{1.96\ (\sqrt{96.56})}{18} = 1.07$$

$$BT = \left(\frac{1.07}{.05}\right)^2 \times 18 = 8243 \qquad \underline{\underline{8300}}\ \text{TMU}$$

2. HA32:

$$r = \frac{1.96\ (\sqrt{98.71})}{34} = 0.573$$

$$BT = \left(\frac{0.573}{.05}\right)^2 \times 34 = 4465 \qquad \underline{\underline{4500}}\ \text{TMU}$$

3. HB6:

$$r = \frac{1.96\ (\sqrt{99.23})}{34} = .574$$

$$BT = \left(\frac{.574}{.05}\right)^2 \times 34 = 4481 \qquad \underline{\underline{4500}}\ \text{TMU}$$

4. HB32:

$$r = \frac{1.96\ (\sqrt{167.12})}{48} = .528$$

$$BT = \left(\frac{.528}{.05}\right)^2 \times 48 = 5352 \qquad \underline{\underline{5400}}\ \text{TMU}$$

TRANSPORT

5. TA6:

$$r = \frac{1.96\ (\sqrt{32.61})}{7} = 1.6$$

$$BT = \left(\frac{1.6}{.05}\right)^2 \times 7 = 7168 \qquad \underline{\underline{7200}}\ \text{TMU}$$

6. TA32:

$$r = \frac{1.96\ (\sqrt{45.9})}{16} = 0.83$$

$$BT = \left(\frac{.83}{.05}\right)^2 \times 16 = 4409 \qquad \underline{\underline{4400}}\ \text{TMU}$$

7. TB6:

$$r = \frac{1.96\ (\sqrt{101.92})}{21} = 0.943$$

$$BT = \left(\frac{.943}{.05}\right)^2 \times 21 = 7470 \qquad \underline{\underline{7500}}\ \text{TMU}$$

8. TB32:

$$r = \frac{1.96\ (\sqrt{102.13})}{29} = .683$$

$$BT = \left(\frac{.683}{.05}\right)^2 \times 29 = 5411 \qquad \underline{\underline{5400}}\ \text{TMU}$$

A confidence level of 95% was used to obtain the critical region of $T < -2.365$ and $T > 2.365$, with 7 degrees of freedom.

Calculations for the "t" test statistic gave a value of 0.55, which fell within the range $-2.365 < t < 2.365$. Therefore, from the data provided, it can be concluded that the accuracy of MTM-3 does not deviate greater than ±5% at the 95% confidence level, when compared to MTM-1.

Table 19: MTM-3 - "T" Test

$H_0: \mu_D = d_0$

$H_1: \mu_D \neq d_0$

$\alpha = 0.05$

$\nu = 7$

$\Sigma d = 241.3$

$\Sigma d^2 = 176{,}242.6$

Critical region:

$T_{\alpha/2,7}$ $\quad T_{.025} < -2.365 \quad T_{.025} > 2.365$

"t" test statistic:

$$t = \bar{D} - d_0 / S_d/\sqrt{n}$$

$$\bar{D} = \Sigma d/n = 241.3/8 = 30.2$$

$$S_d^2 = n\Sigma d^2 - (\Sigma d)^2 / n(n-1)$$

$$= 8\ (176{,}242.6) - (241.3)^2 / 8(7)$$

$$= 1{,}409{,}940.8 - 58{,}225.7 / 56$$

$$= 24{,}137.8$$

$$S_d = \sqrt{24{,}137.8} = 155.4$$

$$t = 30.2 - 0 / 155.4/\sqrt{8}$$

$$= 0.55$$

The values of the studies provided are shown in Table 20. The deviation and percent deviation for each study was calculated and summed.

Table 20: MTM-3 vs. MTM-1

ACTIVITY	MTM-1	MTM-3	DEVIATION	% DEVIATION
1	11575	11347	-228	-2.0
2	5761.1	5903	141.9	2.5
3	5655	5760	105	1.8
4	7954.4	8178	223.6	2.8
5	7530.9	7512	- 18.9	-0.3
6	7522.1	7392	-130.1	-1.7
7	8445.8	8606	160.2	1.9
8	11997.4	11985	- 12.4	-0.1
TOTAL	66441.7	66683	241.3	.36

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be 0.36%. Based on the accumulated system accuracy formula, such a deviation will reflect an overall system accuracy of ±5.0% at a 95% confidence level.

MTM-MEK

MTM-MEK is a system developed for small-lot or unique job applications. The accuracy data provided for this system was based upon a comparison of MTM-MEK to MTM-1. Thirteen operations were filmed and timed, using the two systems. The average length of the operations studied was 1550 TMU for MTM-1 and 1600 TMU for MTM-MEK.

Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of MTM-MEK will not deviate greater than ±5% when compared to MTM-1 was tested (see Table 21). A confidence level of 95% was used to obtain the critical region of $T < -2.179$ and $T > 2.179$ with 12 degrees of freedom.

Calculations for the "t" test statistic gave a value of 1.159, which fell within the range $-2.179 < t < 2.179$. Therefore, from the data provided, it can be concluded that the accuracy of MTM-MEK does not deviate greater than ±5 at the 95% confidence level, when compared to MTM-1.

TABLE 21
MTM-MEK "T" TEST

$H_0: \mu_D = d_0$
$H_1: \mu_D = d_0$

$\alpha = 0.05$
$\nu = 12$

Critical region:

$T_{\alpha/2} = T_{.025} < -2.179 \quad T_{.025} > 2.179$

"t" test statistic:

$$t = (\bar{D} - d_0) / (S_d / \sqrt{n})$$

$\bar{D} = 646/13 = 49.69$

$S^2_d = [n \Sigma d^2 - (\Sigma d)^2] / n(n-1)$

$= [13(319{,}028) - (646)^2] / 13(12)$
$= (4147364 - 417316)/156$
$= 23911$

$S_d = \sqrt{23911} = 154.6$

$t = (49.69-0) / 154.6 / \sqrt{13}$

$= 49.69 / 42.878$
$= 1.159$
$-2.179 < 1.159 < 2.179$

The values of the studies provided are shown in Table 22. The deviation and percent deviation for each study was calculated and summed.

TABLE 22
MTM-MEK vs. MTM-1

ACTIVITY	MTM-1	MTM-MEK	DEVIATION	% DEVIATION
1	1261	1390	129	10.23
2	1439	1670	231	16.05
3	1018	1170	152	14.93
4	647	760	113	17.46
5	2043	2270	227	11.11
6	1879	2090	211	11.23
7	1037	910	-127	12.25
8	1802	1770	-32	1.78
9	703	680	-23	3.27
10	2034	1750	-284	13.96
11	1174	1100	-74	6.30
12	1612	1620	8	.50
13	3505	3620	115	3.28
TOTAL	20,154	20,800	646	3.20

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be 3.20%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±5.94% at a 95% confidence level.

MTM-UAS

MTM-UAS (Universal Analyzing System) is a system developed for application with batch jobs. The accuracy data provided was based upon a comparison between MTM-UAS and MTM-1. Eight operations were filmed and timed, using the two systems. The average length of operations studied was 1476 TMU for MTM-1

and 1458 TMU for MTM-UAS. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of MTM-UAS will not deviate greater than $\pm 5\%$ when compared to MTM-1 was tested. The calculations for this test are shown on Table 23. A confidence level of 95% was used to obtain the critical region of $T < -2.365$ and $T > 2.365$, with seven degrees of freedom.

Calculations for the "t" test statistic gave a value of -1.145, which fell within the range $-2.365 < t < 2.365$. Therefore, from the data provided, it can be concluded that the accuracy of MTM-UAS does not deviate greater than $\pm 5\%$ at the 95% confidence level, when compared to MTM-1.

TABLE 23

MTM-UAS "T"-TEST

$H_0: \mu_D = d_0$

$H_1: \mu_D \neq d_0$

$\alpha = 0.05 \;, \quad \nu = 7$

<u>Critical Region:</u>

$T_{\alpha/2} = T_{.025} < -2.145 \quad T_{.025} > 2.145$

$\Sigma d = -149$

$\Sigma d^2 = 17585$

$t = (\overline{D} - d_0) \;/\; (S_d \;/ \sqrt{n})$

$\overline{D} = -149/8 = -18.625$

$S^2_d = [n \, \Sigma d^2 - (\Sigma d)^2] \;/\; n(n-1)$

$= [8(17585) - (-149)^2] \;/\; 8(7)$

$= 2116$

$S_d = \sqrt{2116} = 46$

$t = (-18.625 - 0) / 46/\sqrt{8}$

$= -1.145 \qquad -2.365 < -1.145 < 2.365$

The values of the studies provided are shown in Table 24. The deviation and percent deviation for each study was calculated and summed.

Table 24

MTM-UAS vs. MTM-1

ACTIVITY	MTM-1	UAS	DEVIATION	% DEVIATION
1	1080	990	-90	-8.3
2	1365	1330	-35	-2.6
3	1005	965	-40	-4.0
4	1365	1405	40	2.9
5	1741	1770	29	1.7
6	1880	1875	-5	-0.3
7	830	845	15	1.8
8	2543	2480	-63	2.5
TOTAL	11,809	11,660	-149	1.26

CONCLUSION

Based on the above sample the average deviation between the two systems was found to be 1.26%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±5.16% at a 95% confidence level.

MTM-M

MTM-M was developed for applications in micro-assembly using a stereoscopic microscope. Evaluation as to the accuracy of MTM-M was based on sample data provided by the system vendor in which nine samples of MTM-M values to time study values were compared. The average length of the operations studied was 705 TMU for time study and 700 for MTM-M. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of MTM-M will not deviate greater than ±5% when compared to time study was tested. (See Table 25.)

A confidence level of 95% was used to obtain the critical region of $T < -2.306$ and $T > 2.306$, with 8 degrees of freedom.

Calculations for the "t" test statistic gave a value of -0.535, which fell within the range $-2.306 < t < 2.306$. Therefore, from the data provided, it can be concluded that the accuracy of MTM-M does not deviate greater than ±5% at the 95% confidence level, when compared to time study.

Table 25

MTM-M - "T" Test

H_0: $\mu_D = d_0$

H_1: $\mu_D \neq d_0$

$\alpha = 0.05$

$\nu = 8$

$\Sigma d = -75.3$ TMU

$\Sigma d^2 = 17631.55$ TMU^2

Critical region:

$T_{\alpha/2,\ 8}$ $\quad$ $T_{.025} < -2.306$ $\quad$ $T_{.025} > 2.306$

"t" test statistic:

$$t = \overline{D} - d_0 / S_d/\sqrt{n}$$

$\overline{D} = \Sigma d/n = -75.3/9 = -8.37$ TMU

$S_d{}^2 = n\Sigma d^2 - (\Sigma d)^2 / n(n-1)$

$= 9(17631.55) - (-8.37)^2 / 9(8)$

$= 2202.97$

$S_d = \sqrt{2202.97} = 46.94$ TMU

$t = -8.37 - 0 / 46.94/\sqrt{9}$

$= -0.535$

$$-2.306 < -0.535 < 2.306$$

The values of the studies provided are shown in Table 26. The deviation and percent deviation for each study was calculated and summed.

Table 26
MTM-M vs. Time Study

ACTIVITY	TIME STUDY	MTM-M	DEVIATION	% DEVIATION
1	675.0	671.7	-3.3	-0.5
2	462.0	487.0	25	5.4
3	408.0	406.0	-2	-0.5
4	455.8	365.1	-90.7	-19.9
5	900.2	948.9	48.7	5.4
6	267.0	271.0	4	1.5
7	544.0	542.0	-2	-0.4
8	1885.0	1808.2	-76.8	-4.1
9	775.5	797.3	21.8	2.8
TOTAL	6372.5	6297.2	-75.3	1.18

CONCLUSION

Based on the above sample, the average deviation between MTM-M and time study was found to be 1.18%.

In addition, the regression equations and data-table values for the MTM-M elements were presented in the paper, "MTM-M Magnification Research Project," and were reviewed for accuracy and approach. A sample of representative checks on these equations is presented in Table 27. The regression equations are listed with their correlation coefficient (r value) and the standard error calculated for each equation. From this data, the Research Consortium constructed a chart to determine the number of non-repetitive cycle time TMUs required to achieve a desired ±% accuracy at the 95% confidence level. This chart shows two lines for the MTM-M data. The first includes table error only (i.e., the error from using a discrete value to represent a range of continuous values), while the second line gives the overall system error (table error plus regression error). For a 5% level of accuracy, a job would have to have a cycle time of approximately 1050 TMU.

Table 27

Check of Data Table Based Upon Regression Equations

I. Inside to Inside Table

IIET - A = 3.69 + 1.75 (ID) + .68 (POW-20) + 2.08 (ISIMO)

		Check	Table
0:	3.69 + 1.75 (.322) + 0 + 0 =	4.25	4.3
1:	3.69 + 1.75 (1.17) + 0 + 0 =	5.74	5.7
2:	3.69 + 1.75 (2.17) + 0 + 0 =	7.49	7.5
3:	3.69 + 1.75 (3.17) + 0 + 0 =	9.24	9.2
4:	3.69 + 1.75 (4.17) + 0 + 0 =	10.99	11.0
5:	3.69 + 1.75 (5.21) + 0 + 0 =	12.81	12.8
6:	3.69 + 1.75 (6.23) + 0 + 0 =	14.59	14.6
7:	3.69 + 1.75 (7.23) + 0 + 0 =	16.34	16.3

		Check	Table
8:	3.69 + 1.75 (8.23) + 0 + 0 =	18.09	18.1
9:	3.69 + 1.75 (9.10) + 0 + 0 =	19.62	19.6
10:	3.69 + 1.75 (10.07) + 0 + 0 =	21.31	21.3

IIET - B = 2.26 + 4.56 (ID)

			Check	Table
0:	2.26 + 4.56 (.322)	=	3.73	3.7
1:	2.26 + 4.56 (1.17)	=	7.60	7.6
2:	2.26 + 4.56 (2.17)	=	12.16	12.2
3:	2.26 + 4.56 (3.17)	=	16.72	16.7
4:	2.26 + 4.56 (4.17)	=	21.28	21.3
5:	2.26 + 4.56 (5.21)	=	26.02	26.0
6:	2.26 + 4.56 (6.23)	=	30.67	30.7
7:	2.26 + 4.56 (7.23)	=	35.23	35.2
8:	2.26 + 4.56 (8.23)	=	39.79	39.8
9:	2.26 + 4.56 (9.10)	=	43.76	43.8
10:	2.26 + 4.56 (10.07)	=	48.18	48.2

CONCLUSION

The regression equations and table values were checked, and the approach to the design of MTM-M appears to be valid and correct.

MTM-V

The **MTM-V** system was developed for use in determining the time for manual work associated with machining operations. A summary of the derivation of the construction elements was provided by the system vendor for review. The total TMUs analyzed were divided by the number of analyses performed for each element to obtain a TMU value along with a variance for each element calculated. TMU values were rounded to the nearest 10, and variance values were rounded to the nearest whole number. From the construction elements, the TMU values for the simple and complex elements were calculated. Variance

calculations were also developed for complex elements, and the element variances were added to obtain a single value. Using the formula $x \pm 2 \quad s^2$, a 95% confidence interval was constructed for each element.

From the data presented, the approach used to develop the MTM-V elements appears to be valid and sound. In addition, all elements are shown with ±5% accuracy at a 95% confidence interval with these calculations also appearing to be valid.

CONCLUSION

Based on this review, it was concluded that the calculations used to develop the MTM-V values were valid. In summary, the MTM-V elemental values will reflect an accuracy of ±5% at a 95% confidence level.

MTM-TE

MTM-TE was developed to establish standards in the electronic testing environment.

Evaluation as to the accuracy of MTM-TE was based on sample data provided by the system vendor in which 18 samples of MTM-TE values to MTM-1 values were compared. The average length of the operations studied was 1579 TMU for MTM-1 and 1551 for MTM-TE. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of MTM-TE will not deviate greater than ±5% when compared to MTM-1 was tested. (See Table 28.)

A confidence level of 95% was used to obtain the critical region of $T < -2.110$ and $T > 2.110$, with 17 degrees of freedom.

Calculations for the "t" test statistic gave a value of -.668, which fell within the range $-2.110 < t < 2.110$. Therefore, from the data provided it can be concluded that the accuracy of MTM-TE does not deviate greater than ±5% at the 95% confidence level, when compared to MTM-1.

Table 28
MTM-TE - "T" Test

$H_0: \mu_D = d_0$

$H_1: \mu_D \neq d_0$

$\alpha = 0.05$

$\nu = 17$

$\Sigma d = -502.5$ TMU

$\Sigma d^2 = 548,552.33$

Critical region:

$T_{\alpha/2,\ 17}$ $\quad T_{.025} < -2.110 \quad T_{.025} > 2.110$

"t" test statistic:

$$t = \bar{D} - d_0 / S_d/\sqrt{n}$$

$\bar{D} = \Sigma d/n = -502.5/18 = -27.92$

$S_d^2 = n\Sigma d^2 - (\Sigma d)^2 / n(n-1)$

$= 18(548,552.33) - (-502.5)^2 / 18(17)$

$= 9,873,941.9 - 252,506.25/306$

$= 31,442.6$

$S_d = \sqrt{31,442.6} = 177.32$

$t = -27.92 - 0 / 177.32/\sqrt{18}$

$= -.668$

The values of the studies provided are shown in Table 29. The deviation and percent deviation for each study was calculated and summed.

Table 29

MTM-TE vs. MTM-1

ACTIVITY	MTM-1	MTM-TE	DEVIATION	% DEVIATION
1	133.2	128	-5.2	-3.9
2	1251.6	1086	-165.6	-13.2
3	1536.4	1564	27.6	1.8
4	2185	2116	-69	-3.2
5	734.4	765	30.6	4.2
6	270	279	9	3.3
7	1769.6	1736	-33.6	-1.9
8	1485	1575	90	6.1
9	4873.2	5109	235.8	4.8
10	5069.2	4636	-433.2	-8.5
11	1903.8	2052	148.2	7.8
12	86	120	34	39.5
13	1400.7	1155	-245.7	-17.5
14	637.8	669	31.2	4.9
15	1476	1737	261	17.7
16	902.4	831	-71.4	-7.9
17	2401.2	2079	-322.2	-13.4
18	300	276	-24	-8.0
TOTAL	28415.5	27913	-502.5	1.77

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be 1.77%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±5.30% at a 95% confidence level.

BASIC MOST®

The **MOST®** system differs from other predetermined time systems in its conceptual design by starting with a stated leveling time and determining which motion elements fall within a time bracket. In contrast, other systems start with selected motion elements and then obtain the time duration of the operation.

The system error and balance time calculations for MOST® were reviewed and presented in the paper entitled "Precision Analysis of MTM-1 and MOST®" by W. D. Brinckloe and M. T. Coughlin. The time intervals in MOST® were calculated using a ±5% allowed deviation from the mean for each group. Other assumptions of the MOST® system include:

T_p	=	total planning time	=	40 hours
F	=	fraction of total time on measured work	=	100%
P	=	average performance on measured work	=	115%
F_p	=	process-time fraction	=	10%
F_m	=	manual-time fraction (MOST® applicability)	=	90%
F_a	=	allowance-time fraction	=	12%

Brinckloe calculated the variance of each time interval by using the formula $\sigma^2_{Total} = \sigma^2_{mean} + \sigma^2_{off\ ctr}$,where σ^2 mean is the variance of the range and σ^2 off ctr is the variance due to the mean being off center or not in the middle of the range. A check was performed on these calculations (see Table 30), with the results matching those obtained by the Brinckloe study.

The balance time for each interval was then calculated by Brinckloe, using the formulas from the MTM-1 calculations. These calculations were checked and are presented in Table 31. Based on this review, it was found that all results were within ±5 TMU, allowing for round-off error. (Brinckloe did not carry out the calculations in his study, although he showed two significant digits in his results. This check shows that he must have carried more digits during his computations.)

To construct a weighted average of the balance time for MOST®, Brinckloe stated that a random draw of several MOST® jobs was made, producing 3470 motions. The motions were grouped according to their TMU value and the frequency for each TMU range was calculated. A check of this procedure is documented in Table 32. From these frequencies and the calculated balance time for each TMU interval, Brinckloe obtained an estimated balance time of 3235 TMU as shown in Table 33.

Table 30
Check of Variance Calculations

1. 10 TMU = $\overline{x}$
   1 - 17 = range

$$\sigma^2 = \frac{(17-1)^2}{12} + \left(\frac{(10-1) - (17-10)}{2}\right)^2 = 21.33 + 1 = \underline{\underline{22.33}}$$

2. 30 TMU = $\overline{x}$
   17-42 = range

$$\sigma^2 = \frac{(42-17)^2}{12} + \left(\frac{(30-17) - (42-30)}{2}\right)^2 = 52.08 + .25 = \underline{\underline{52.33}}$$

3. 60 TMU = $\overline{x}$
   42-77 = range

$$\sigma^2 = \frac{(77-42)^2}{12} + \left(\frac{(60-42) - (77-60)}{2}\right)^2 = 102.08 + .25 = \underline{\underline{102.33}}$$

4. 100 TMU = $\overline{x}$
   77-126 = range

$$\sigma^2 = \frac{(126-77)^2}{12} + \left(\frac{(100-78) - (126-100)}{2}\right)^2 = 200.08 + 4.0 = \underline{\underline{204.08}}$$

5. 160 TMU = $\bar{x}$
126–196 = range

$$\sigma^2 = \frac{(196-126)^2}{12} + \left(\frac{(160-127) - (196-160)}{2}\right)^2 = 408.33 + 2.25 = \underline{\underline{410.58}}$$

6. 540 TMU = $\bar{x}$
477–601 = range

$$\sigma^2 = \frac{(601-477)^2}{12} + \left(\frac{(540-477) - (601-540)}{2}\right)^2 = 1281.33 + 1 = \underline{\underline{1282.33}}$$

Table 31
Check of Balance Time Calculations

1. 10 TMU

$\sigma^2 = 22.33$ $\quad$ $\sigma = 4.725$ $\quad$ $1.96\sigma = 9.261$

$$\pm r = \frac{9.261}{10} = .926$$

$$n = \left(\frac{.926}{.05}\right)^2 = 343 \times 10 = \underline{\underline{3430}} \quad \text{vs.} \quad 3431$$

$$n = \left(\frac{.926}{.0553}\right)^2 = 280.4 \times 10 = \underline{\underline{2804}} \quad \text{vs.} \quad 2805$$

2. 30 TMU

$\sigma^2 = 52.33$ $\quad$ $\sigma = 7.234$ $\quad$ $1.96\sigma = 14.18$

$$\pm r = \frac{14.18}{30} = .473$$

$$n = \left(\frac{473}{.05}\right)^2 = 89.49 \times 30 = \underline{\underline{2685}} \quad \text{vs.} \quad 2680$$

$$n = \left(\frac{.473}{.0553}\right)^2 = 73.15 \times 30 = \underline{\underline{2195}} \quad \text{vs.} \quad 2191$$

3. 60 TMU

$\sigma^2 = 102.33 \qquad \sigma = 10.12 \qquad 1.96\,\sigma = 19.84$

$\pm r = \frac{19.84}{60} = .3307$

$n = \left(\frac{.3307}{.05}\right)^2 = 43.74 \times 60 = \underline{\underline{2624}} \qquad \text{vs.} \qquad 2621$

$n = \left(\frac{.3307}{.0553}\right)^2 = 35.76 \times 60 = \underline{\underline{2146}} \qquad \text{vs.} \qquad 2142$

4. 100 TMU

$\sigma^2 = 204.08 \qquad \sigma = 14.285 \qquad 1.96\,\sigma = 28.0$

$\pm r = \frac{28}{100} = .280$

$n = \left(\frac{.280}{.05}\right)^2 = 31.36 \times 100 = \underline{\underline{3136}} \qquad \text{vs.} \qquad 3136$

$n = \left(\frac{.280}{.0553}\right)^2 = 25.63 \times 100 = \underline{\underline{2563}} \qquad \text{vs.} \qquad 2564$

5. 160 TMU

$\sigma^2 = 410.58 \qquad \sigma = 20.26 \qquad 1.96\,\sigma = 39.72$

$\pm r = \frac{39.72}{160} = .248$

$n = \left(\frac{.248}{.05}\right)^2 = 24.6 \times 160 = \underline{\underline{3936}} \qquad \text{vs.} \qquad 3943$

$n = \left(\frac{.248}{.0553}\right)^2 = 20.11 \times 160 = \underline{\underline{3218}} \qquad \text{vs.} \qquad 3223$

6. 540 TMU

$\sigma^2 = 1282.33 \qquad \sigma = 35.81 \qquad 1.96\,\sigma = 70.19$

$\pm r = \frac{70.19}{540} = .13$

$n = \left(\frac{.13}{.05}\right)^2 = 6.76 \times 540 = \underline{\underline{3650}} \qquad \text{vs.} \qquad 3649$

$n = \left(\frac{.13}{.0553}\right)^2 = 5.53 \times 540 = \underline{\underline{2984}} \qquad \text{vs.} \qquad 2983$

Table 32

Frequency Check for Most Intervals

	TMU	OBSERVATIONS	FREQUENCY (%)	FREQUENCY % (ON 3461)
*	10	2401	69.2	69.4
*	30	555	16.0	16.04
*	60	319	9.2	9.2
*	100	84	2.42	2.4
*	160	45	1.3	1.3
	240	7	.2	
*	320	31	.9	.9
*	420	11	.32	.3
*	540	14	.4	.4
	670	0	0	
	810	1	.03	
	960	1	.03	

* Used by Brinckloe in Estimated Balance Time Calculation

Table 33

Estimated Balance Time - MOST®

TMU	BALANCE TIME	FREQUENCY	EXPECTED BAL. TIME
10	3431	69.4%	2381.11
30	2680	16.1	431.48
60	2621	9.2	241.13
100	3136	2.4	75.26
160	3943	1.3	51.26
320	3171	0.9	28.54
420	3757	0.3	11.27
540	3649	0.4	14.60
			3234.65

Estimated MOST Balance Time	=	3235

In his study, Brinckloe also presented two example comparisons between MTM-2 and MOST® motions. The calculation of variance for the two examples illustrated that MOST® does not contain additional error from its reference to MTM-1 and MTM-2 data.

A review of the MOST® system, based upon the results presented in "Precision Analysis of MTM-1 and MOST®" by W. D. Brinckloe, showed the assumptions of the construction of MOST® to be valid, and the calculations of the system error and balance time to be correct.

CONCLUSION

Based on the review of the Brinckloe study, it was determined that the system error for the Basic MOST® (Maynard Operation Sequence Technique) system to be ±5% at the 95% confidence level. In addition, the system has an estimated balance time of 3235 TMU. In summary, for operations of a length of 3235 TMUs or longer, MOST® will reflect a system accuracy of ±5% at a 95% confidence level.

MINI MOST®

Mini MOST® consists of the same sequence models and index numbers as Basic MOST®, but is used with a multiplier of one instead of 10. In the paper, "Precision Analysis of Short-Cycle MOST®," W. D. Brinckloe reviews the backup benchmark analysis and basic motions from MTM-1 that make up Mini MOST®. The four motions of Action Distance (A), Body Motion (B), Gain Control (G), and Place (P) from the General Move category have been modified to be used for work of short duration. The accuracy of each of these motions was calculated. Using the frequency data from "The MTM-2 Project," Brinckloe then calculated the balance time for Mini MOST®.

The Action Distance motion consists of three categories: hand movement, linear; hand movement, angular; and leg movement. The hand movement, linear times are derived from the MTM-1 motions of Reach-Cases A and B and Move-Cases A and B. The weighted TMU and variance for this category was found to be 6.813 TMU and 1.611 TMU^2, respectively. The hand movement, angular, category is taken from the MTM-1 Turn motion with the 30^0 time value deleted. The overall weighted TMU and variance calculated was 4.815 TMU and 0.781 TMU^2. The leg movement category consists of the MTM-1 leg motion and horizontal motions (SS-C1, SS-C2, TBC1, TBC2, W-P and WPO) for one and two steps. The overall weighted TMU and variance was 17.6 TMU and 9.218 TMU^2. Next, Brinckloe calculated the probability that the underlying MTM-1 error would push the correct elemental motion time into the next lower or higher index range. Combining these results with the previous calculations, Brinckloe arrives at a balance time of 401 TMU for Action Distance, with a variance of 2.293 TMU^2.

The next motion, Body Movement, consists of only one index value. This was derived from the MTM-1 motions of Bend (29.0 TMU) and Arise (31.9 RMU). The calculated balance time is 216 TMU with a variance of 4.505 TMU^2. The Gain Control motion has five index values. Each of these index values were analyzed separately and then combined with a weighted average to obtain the balance time. The variance for the index value was combined with the calculated variance from the MTM-1 data card value (as was done for Action Distance). Total balance time was 656 TMU, with a variance of 3.628 TMU^2.

The data for the fourth motion, Place, was not available for review. Based on discussions with Brinckloe, he substantiated that the computations had been performed in the same manner and had resulted in a balance time of approximately 400 TMU.

Using the frequency data, an overall system balance time for Mini MOST® was calculated and the result was 501.4 TMU (rounded to 500 TMU). From the review of the available data, the construction of the Mini MOST® index values appears valid and correct. For operations totaling 500 TMU, the accuracy would be ±5% at the 95% confidence level.

MAXI MOST®

Maxi MOST® was developed to be used for long-cycle jobs such as shipbuilding or large-truck assembly. An evaluation as to the accuracy of Maxi MOST® was based on sample data provided by the system vendor in which 35 samples of Maxi MOST® values were compared to Basic MOST® values. The average length of the operations studied was 6512 TMU for Basic MOST®, and 6558 TMU for Maxi MOST®. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of Maxi MOST® will not deviate greater than ±5% when compared to Basic MOST® was tested. (See Table 34.)

A confidence level of 95% was used to obtain the critical region of $T < -2.042$ and $T > 2.042$, with 34 degrees of freedom.

Calculations for the "t" test statistic gave a value of 0.72, which fell within the range $-2.042 < t < 2.042$. Therefore, from the data provided, it can be concluded that the accuracy of Maxi MOST® does not deviate greater than ±5% at the 95% confidence level, when compared to Basic MOST®.

Table 34
Maxi MOST® - "T" Test

H_0: $\mu_D = d_0$

H_1: $\mu_D \neq d_0$

$\alpha = 0.05$

$\nu = 34$ - 30

$\sum d = 1{,}638$

$\sum d^2 = 1{,}433{,}890$

Critical region:

$T_{\alpha/2,\ 34}$ $T_{.025} < -2.042$ $T_{.025} > 2.042$

"t" test statistic:

$$t = \overline{D} - d_0 \;/\; S_d/\sqrt{n}$$

$\overline{D} = \sum d/n = 1{,}638/35 = 46.8$

$S_d^2 = n\sum d^2 - (\sum d)^2 \;/\; n(n-1)$

$= 35(1{,}433{,}890) - (1{,}638)^2 \;/\; 35(34)$

$= 39{,}919$

$S_d = \sqrt{39{,}919} = 200$

$t = 46.8 - 0 \;/\; 200/\sqrt{35} = 1.405$

$-2.042 < 1.405 < 2.042$ Therefore, accept H_0

Total Error: 1,638/227,908 x 100 = 0.72%

The values of the studies provided are shown in Table 35. The deviation and percent deviation for each study was calculated and summed.

Table 35

Maxi MOST® vs. Basic MOST®

ACTIVITY	BASIC MOST	MAXI MOST	DEVIATION	% DEVIATION
1	13258	13900	642	4.8
2	2040	2000	-40	-2.0
3	10080	10100	20	0.2
4	1508	1680	172	11.4
5	10210	10700	490	4.8
6	41570	41400	-170	-0.4
7	828	700	-128	-15.5
8	1060	1200	140	13.2
9	1410	1300	-110	-7.8
10	1690	1700	10	0.6
11	1780	1900	120	6.7
12	4940	4800	-140	-2.8
13	2440	2500	60	2.5
14	15428	15200	-228	-1.5
15	6590	6500	-90	-1.4
16	5840	6200	360	6.2
17	22378	22500	122	0.5
18	3470	3400	-70	-2.0
19	1408	1400	-8	-0.6
20	5000	5100	100	2.0
21	950	900	-50	-5.3
22	27236	27400	164	0.6
23	987	1000	13	1.3
24	4240	4200	-40	-0.9
25	986	1266	280	28.4

ACTIVITY	BASIC MOST	MAXI MOST	DEVIATION	% DEVIATION
26	2740	2600	-140	-5.1
27	2530	2500	-30	-1.2
28	1390	1300	-90	-6.5
29	8431	8300	-131	-1.6
30	870	900	30	3.4
31	2560	2600	40	1.6
32	1790	1600	-190	-10.6
33	12250	12700	450	3.7
34	1550	1500	-50	-3.2
35	6470	6600	130	2.0
TOTAL	227908	229546	1638	0.72

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be 0.72%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±5.05% at a 95% confidence level.

MTS

MTS (Motion Time Survey) is a predetermined time system that was developed by General Electric. Although the derivation of the system's values was not provided, a study performed by the United States Air Force was provided for our review. The study compared 15 samples of MTS values to MTM values. The average length of the operations studied was 11,151 TMU for MTM-1, and 10,584 TMU for MTS. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of MTS will not deviate greater than ±5% when compared to MTM-1 was tested (see Table 36).

A confidence level of 95% was used to obtain the critical region of T < -2.145 and T > 2.145, with 14 degrees of freedom.

Calculations for the "t" test statistic gave a value of -0.732, which fell within the range $-2.145 < t < 2.145$. Therefore, from the data provided, it can be concluded that the accuracy of MTS does not deviate greater than ±5% at the 95% confidence level, when compared to MTM-1.

Table 36
MTS - "T" Test

$H_0: \mu_d = d_0$
$H_1: \mu_d \neq d_0$

$\alpha = 0.05$
$\nu = 14$

$T_{\alpha/2} = T_{.025} < -2.145 \quad T_{.025} > 2.145$

$\Sigma d = -.08504$

$\Sigma d^2 = 0.0131394$

$t = (\overline{D} - do) / (Sd / \sqrt{n})$

$\overline{D} = - .0.08504/15 = -.00567$

$S^2_d = [n \Sigma d^2 - (\Sigma d)^2] / n(n-1)$

$= [15(.0131394) - (-.08504)^2] / 15(14)$

$= .0009$

$S_d = \sqrt{.0009} = .03$

$t = (-.00567-0) / (.03 / \sqrt{15}$

$= -0.732 \qquad -2.145 < -.732 < 2.145$

The values of the studies provided are shown in Table 37. The deviation and percent deviation for each study was calculated and summed.

Table 37
MTS vs. MTM-1

ACTIVITY	MTM	MTS	DEVIATION	% DEVIATION
1	.0033	.0034	.0001	3.03
2	.01116	.0086	-.00023	2.06
3	.009	.0083	-.0007	7.78
4	.01872	.0174	-.00132	7.05
5	.0012	.0014	.0002	16.67
6	.00714	.009	.00186	26.05
7	.00636	.006	-.00036	5.66
8	.00387	.00315	-.00072	18.60
9	.13602	.1546	.01858	13.66
10	.15642	.1639	.00748	4.78
11	.08976	.0982	.00844	9.40
12	.20406	.1502	-.05386	26.39
13	.40218	.3241	-.07808	19.41
14	.2691	.2916	.0225	8.36
15	.3544	.3478	-.0066	1.86
TOTAL	1.67269	1.58765	-.08271	5.08

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be 5.08%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±7.12% at a 95% confidence level.

MANPRO™

MANPRO™ is a generalized standard data system which uses composite work and motion patterns that are applied to the work being analyzed. There are 100 elements contained within nine categories. The standard hours for each of these elements were derived from micromotion analysis, which was not available for review.

The accuracy data provided was based upon a comparison between MANPRO™ and MTM-1. The study compared nine samples of MANPRO™ values to MTM-1 values. It should be noted that MANPRO™ shows a systematic bias to underestimate the MTM-1 elemental value. The average length of the operations studied was 52 TMU for MTM-1 and 48 TMU for MANPRO™. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of MANPRO™ will not deviate greater than ±5% when compared to MTM-1 was tested (see Table 38). A confidence level of 95% was used to obtain the critical region of $T < -2.306$ and $T > 2.306$ with 8 degrees of freedom. Calculations for the "t" test statistic gave values of -3.259, which fell outside the range <-2.306. Therefore, from the data provided, it can be concluded that the accuracy of MANPRO™ deviates greater than ±5% at the 95% confidence level, when compared to MTM-1.

Table 38

MANPRO" - "T" Test

$H_0: \mu_D = d_0$

$H_1: \mu_D \neq d_0$

$\alpha = 0.05$

$v = 8$

$\Sigma d = -.00031$

$\Sigma d^2 = .0000000185$

$T_{\alpha/2} = T_{.025} < -2.306 \quad T_{025} > 2.306$

$t = (\bar{D} - do) / S_d / \sqrt{n}$

$\bar{D} = -.00031/9 = -.000034$

$S^2_d = [n \Sigma d^2 - (\Sigma d)^2] / n(n-1)$

$= [9(.0000000185) - (-.00031)^2] / 9(8)$

$= 9.78 \times 10^{-10}$

$S_d = .0000313$

$t = (-.000034 - 0) / .0000313 / \sqrt{9}$

$= -3.259$

The values of the studies provided are shown in Table 39. The deviation and percent deviation for each study was calculated and summed.

Table 39

MANPRO™ vs. MTM-1

ELEMENT TIME TRANSLATIONS

ACTIVITY	MTM-1 (HRS)	MANPRO (HRS)	DEVIATION	% DEVIATION
1	.00115	.00107	-.00008	6.96
2	.00025	.00023	-.00002	8.00
3	.00031	.00030	-.00001	3.22
4	.00050	.00045	.00005	10.00
5	.00022	.00020	-.00002	9.09
6	.00050	.00048	-.00002	4.00
7	.00018	.00017	.00001	5.56
8	.00099	.00098	-.00001	1.01
9	.00054	.00045	-.00009	16.67
TOTAL	.00464	.00433	-.00031	6.63

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be 6.68%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±8.34 % at a 95% confidence level.

CUE

The **CUE** system consists of a number of formulas derived from MTM-1 data. The derivation of these formulas, and the resulting CUE values, were considered proprietary and were not provided for review. The system vendor did provide comparisons to MTM-1 using industrial and textbook studies. The breakdown of these studies is as follows:

SOURCE	STUDIES
Mattel	6
Xerox	18
Whirlpool	3
Square D	22
Karger & Bayha (textbook)	25
TOTAL	74

The studies relating to Mattel and Xerox, were developed by company analysts and provided to CUE developers. The studies relating to Whirlpool, Square D, and textbook cases, were produced by the CUE developer.

The TMU values provided from these studies were used to test the hypothesis as to whether CUE differs significantly from MTM-1. The study compared 74 samples of CUE values to MTM-1 values. The average length of the operations studied was 144 TMU for MTM-1 and 144 TMU for CUE. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of CUE will not deviate greater than ±5% when compared to MTM-1 was tested (see Table 40).

A confidence level of 95% was used to obtain the critical region of $T < 1.96$ and $T > 1.96$, with 73 degrees of freedom.

Calculations for the "t" test statistic gave a value of 1.59, which fell within the range $-1.96 < t < 1.96$. Therefore, from the data provided, it can be concluded that the accuracy of CUE does not deviate greater than ±5% at the 95% confidence level, when compared to MTM-1, shown in Table 40.

Table 40
CUE - "T" Test

$H_0 : \mu_D = d_0$
$H_1 : \mu_D \neq d_0$

$\alpha = 0.05$
$\nu = 73$

$T_{\alpha/2} = T_{.025} < -1.96, \; T_{.025} > 1.96$

$t = (\bar{D} - do) / (S_d / \sqrt{n})$

$\bar{D} = \Sigma d/n = 84.4/74 = 1.14$

$S_d^2 = n\Sigma d^2 - (\Sigma d)^2 / [n(n-1)]$

$= (74)(2860.22) - (84.4)^2 / (74)(73)$

$= 37.86$

$S_d = \sqrt{37.86} = 6.15$

$t = (1.14 - 0) / (6.15 / \sqrt{74})$

$= 1.59$

The values of the studies provided are shown in Table 41. The deviation and percent deviation for each study was calculated and summed.

Table 41

CUE vs. MTM-1

ACTIVITY	MTM-1	CUE	DEVIATION	% DEVIATION
1	52.8	54	1.2	2.27
2	59.4	56	-3.4	5.72
3	72.9	75	2.1	2.88
4	80.4	86	5.6	6.96
5	87.5	90	2.5	2.86
6	90.2	88	-2.2	5.36
7	91.3	90	-1.3	1.42
8	93.1	90	-3.1	3.33
9	106.8	107	0.2	0.18
10	107.5	107	-0.5	0.46
11	109.9	108	-1.9	1.73
12	118.9	123	4.1	3.45
13	125.4	129	3.6	2.87
14	139.1	141	1.9	1.36
15	157.8	162	4.2	2.66
16	176.4	172	-4.4	2.49
17	215.0	217	2.0	0.93
18	238.1	247	8.9	3.74
19	238.6	242	3.4	1.42
20	253.8	256	2.2	0.87
21	317.0	332	15.0	4.73
22	327.3	325	-2.3	1.62
23	329.4	341	11.6	3.52
24	337.8	353	15.2	4.50
25	421.1	424	2.9	0.69
26	585.4	600	14.6	2.49
27	754.7	781	26.3	3.48
28	10.9	11	.1	0.92
29	20.8	19	-1.8	8.65
30	21.0	22	1.0	4.76
31	22.7	21	-1.7	12.73

ACTIVITY	MTM-1	CUE	DEVIATION	% DEVIATION
32	23.5	24	0.5	2.13
33	26.4	26	-0.4	1.52
34	27.6	26	-1.6	5.80
35	29.0	27	2.0	6.90
36	35.7	33	-2.7	7.56
37	40.8	39	-1.8	4.41
38	43.9	43	-0.9	2.05
39	50.6	51	0.4	0.80
40	57.4	56	-1.4	2.44
41	61.5	57	-4.5	7.32
42	62.7	58	-4.7	7.50
43	72.7	78	5.3	7.29
44	77.0	78	1.0	1.30
45	83.7	84	0.3	0.36
46	97.8	88	-9.8	10.02
47	100.7	104	3.3	3.28
48	130.3	130	-0.3	0.23
49	143.1	142	-1.1	0.77
50	152.4	151	-1.4	0.92
51	172.1	174	1.9	1.10
52	349.9	345	-4.9	1.40
53	10.6	11	0.4	1.51
54	10.9	9	-1.9	17.43
55	16.6	14	-2.6	15.66
56	34.4	35	0.6	1.74
57	42.2	41	-1.2	2.84
58	47.6	49	1.4	2.94
59	51.9	50	-1.9	3.66
60	52.6	52	-0.6	1.14
61	59.3	60	0.7	1.18
62	60.1	64	3.9	6.49
63	67.7	70	2.3	3.40
64	68.7	62	-6.7	9.75
65	69.3	71	1.7	2.45

ACTIVITY	MTM-1	CUE	DEVIATION	% DEVIATION
66	78	73	-5.0	6.41
67	80.1	79	-1.1	1.37
68	104.6	99	-5.6	5.35
69	106.7	104	-2.7	2.53
70	120.4	122	1.6	1.33
71	140.1	139	-1.1	0.78
72	163.6	162	-1.6	0.98
73	670.1	663	-7.1	1.06
74	980.3	1006	25.7	2.62
Total:	10,637.60	10,358.80	84.4	2.62

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be 2.62%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±5.64% at a 95% confidence level.

MSD

MSD elements were derived directly from MTM-1 data tables. The deviation of each MSD element can be calculated by using the same methods used in calculating the MTM-1 and MTM-2 deviations. The error for each element would result from MSD using a single value to represent a range of MTM-1 values, plus the error due to rounding the table value. The deviation for the variables in each element (distance, case and class) could also be calculated. However, in the absence of any frequency data for the occurrence of each element, a total system deviation could not be calculated with any certainty.

Evaluation as to the accuracy of MSD was based on sample data provided by the system vendor in which 22 samples of MSD values were compared to MTM values. The average length of the operations studied was 7,373 TMU for MTM-1 and 7,428

for MSD. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of MSD will not deviate greater than ±5% when compared to MTM-1 was tested (see Table 42).

A confidence level of 95% was used to obtain the critical region of $T < -2.08$ and $T > 2.08$, with 21 degrees of freedom.

Calculations for the "t" test statistic gave a value of 1.21, which fell within the range $-2.08 < t < 2.08$. Therefore, from the data provided, it can be concluded that the accuracy of MSD does not deviate greater than ±5% at the 95% confidence level, when compared to MTM-1.

The values of the studies provided are shown in Table 43. The deviation and percent deviation for each study was calculated and summed.

Table 42

MSD - "T" Test

$H_0 : \mu_d = d_0$

$H_1 : \mu_d \neq d_0$

$\alpha = 0.05$

$\nu = 21$

$\Sigma d = 1223$

$\Sigma d^2 = 1,043,257$

$t = (\bar{D} - d_0) / S_d / \sqrt{n}$

$\bar{D} = 1223 / 22 = 55.59$

$S^2{}_d = [n \sum d^2 - (\sum d)2] / n[n-1]$

$= [22\ (1043257) - (1223)^2] / 22\ (21)$

$= 46441$

$S_d = 215.5$

$T_{\alpha/2} = T_{.025} < -2.08,\ T_{.025} > 2.08$

$t = (55.59 - 0) / 215.5 / \sqrt{22}$

$t = 1.21$

$-2.08 < 1.21 < 2.08$

Table 43
MSD vs. MTM-1

ACTIVITY	MTM-1	MSD	DEVIATION	% DEVIATION
1	1,237	1,293	56	4.53
2	1,960	1,883	-77	3.93
3	695	670	-25	3.60
4	4,994	4,961	-33	0.66
5	91,599	91,933	334	0.36
6	8,226	8,279	53	0.64
7	4,721	4,686	-35	0.74
8	991	1,034	43	4.34
9	439	432	-7	1.59
10	1,385	1,420	35	2.53
11	1,146	1,157	11	0.96
12	1,202	1,264	62	5.16
13	994	967	-27	2.72
14	1,099	1,059	-40	3.64
15	7,907	7,845	-62	0.78
16	9,747	9,871	124	1.27

ACTIVITY	MTM-1	MSD	DEVIATION	% DEVIATION
17	3,486	3,416	-70	2.01
18	395	387	-8	2.02
19	434	423	-11	2.53
20	734	733	-1	0.14
21	900	862	-38	4.22
22	17,911	18,850	939	5.24
Total	162,202	163,425	1,223	0.75

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be .75%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±5.06% at a 95% confidence level.

UNIVEL®

UNIVEL® is a computerized data base of standard data formulae. The basis for these formulae was time study taken randomly from a group of 360 manufacturing operations in machining and assembly. Based on these studies, mathematical curves and graphs of the elemental sample data were developed to predict average elemental times within ±5%, 99.7% of the time.

Although original backup data was not available, the vendor did provide a study conducted in 1972 by the A. O. Smith Corporation which compared UNIVEL® to MTM-1. The study compared 20 samples of UNIVEL® values to MTM values. The average length of the operations studied was 247 TMU for MTM-1 and 246 for UNIVEL®. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of UNIVEL® will not deviate greater than ±5% when compared to MTM-1 was tested (see Table 44).

The confidence level of 95% was used to obtain the critical region of $T < -2.539$ and $T > 2.539$, with 19 degrees of freedom.

Calculations for the "t" test statistic gave a value of -0.36%, which fell within the range 2.539 < t < 2.539. Therefore, from the data provided, it can be concluded that the accuracy of UNIVEL® does not deviate greater than ±5% at the 95% confidence level, when compared to MTM-1.

The values of the studies provided are shown in Table 45. The deviation and percent deviation for each study was calculated and summed.

Table 44
UNIVEL® - "T" Test

$H_0: \mu_D = d_0$
$H_1: \mu_D \neq d_0$

$\alpha = 0.05 \;, \quad \nu = 19$

$\Sigma d = -21.05$
$\Sigma d^2 = 3233.56$

Critical Region:

$T_{\alpha/2} = T_{.025} < -2.539 \quad T_{.025} > 2.539$

$t = (\overline{D} - d_0) \,/\, (S_d \,/ \sqrt{n})$

$\overline{D} = -21.05/20 = -1.0525$

$S^2_d = [n\,\Sigma d^2 - (\Sigma d)^2] \,/\, n(n-1)$

$= [20(.0131394) - (-.08504)^2] \,/\, 20(19)$

$= (64671.2 - 443.1) \,/\, 380$

$= 169.02$

$S_d = \sqrt{169.02} = 13$

$t = (-1.0525 - 0) / 13/\sqrt{20}$

$t = -.36 \qquad -2.539 < -.36 < 2.539$

Table 45

UNIVEL® vs. MTM-1

ACTIVITY	MTM-1	UNIVEL	DEVIATION	% DEVIATION
1	28.5	28.22	-0.28	.98
2	62.03	60.44	-1.59	2.56
3	69.25	66.16	-3.09	4.46
4	142	145.77	3.77	2.65
5	414.4	386.6	-27.8	6.71
6	194	186.51	-7.49	3.86
7	157.60	165.19	7.39	4.69
8	247	236.34	-10.66	4.32
9	63.1	58.78	-4.32	6.85
10	496	458.27	-37.73	7.61
11	190.2	193.4	3.2	1.68
12	102.1	107.14	5.04	4.94
13	425.4	432.07	6.67	1.56
14	383.5	403.98	20.48	5.34
15	193.3	189.99	-3.31	1.71
16	85.05	89.13	4.08	4.80
17	482.6	496.79	14.19	2.94
18	367.8	370.04	2.24	0.61
19	474	478.77	4.77	1.01
20	354.9	358.29	3.39	0.96
Total	4,932.93	4,911.88	-21.05	0.42

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be 0.42%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±5.02% at a 95% confidence level.

MODAPTS™

MODAPTS™ was based on research findings of the Australian Association for Predetermined Time Standards and Research. Basic motion time elements were developed from time study and existing predetermined time systems. The "modularity" of the system refers to the findings that all hand, arm, foot and body motions can be expressed as multiples of finger motions.

Although the results of a study which established the accuracy of the MODAPTS™ system would not be released by the firm conducting the study, the vendor did provide data which compared MODAPTS™ to MTM-1. The study compared five samples of MODAPTS™ values. The average length of the operations studied was 689 TMU for MTM-1 and 730 TMU for MODAPTS™. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of MODAPTS™ will not deviate greater than ±5% when compared to MTM-1 was tested (see Table 46).

A confidence level of 95% was used to obtain the critical region of $T < -2.776$ and $T > 2.776$, with 4 degrees of freedom.

Calculations for the "t" test statistic gave a value of 2.235, which fell within the range $-2.776 < t < 2.776$. Therefore, from the data provided, it can be concluded that the accuracy of MODAPTS™ does not deviate greater than ±5% at the 95% confidence level, when compared to MTM-1.

TABLE 46
MODAPTS" - "T" Test

H_0: $\mu_D = d_0$

H_1: $\mu_D \neq d_0$

$\alpha = 0.05$

$\nu = 4$

$\Sigma d = 203.4$

$\Sigma d^2 = 14897.4$

<u>Critical Region:</u>

$T_{\alpha/2}$ $T_{.025} < -2.776$ $T_{.025} > 2.776$

<u>"t" test statistic:</u>

$$t = (\overline{D} - d_0) / S_d/\sqrt{n})$$

$\overline{D} = 203.4/5 = 40.68$

$S_d^2 = (n\Sigma d^2 - (\Sigma d)^2)/n(n-1)$

$= (5(14897.4) - (203.4)^2)/5(4)$

$= 1655.77$

$S_d = \sqrt{1655.77}$

$= 40.69$

$t = (40.68 - 0)/40.69/\sqrt{5}$

$= 2.235$

$-2.776 < 2.235 < 2.776$

The values of the studies provided are shown in Table 47. The deviation and percent deviation for each study was calculated and summed.

TABLE 47

MODAPTS™ VS. MTM-1

ACTIVITY	MTM-1	MODAPTS™	DEVIATION	% DEVIATION
1	149.6	150.6	1.0	.67
2	445.9	451.9	6.0	1.34
3	125.3	154.3	29.0	23.14
4	1039.2	1120.9	81.7	7.86
5	1686.3	1772.0	85.7	5.08
TOTAL	3446.3	3649.7	203.4	5.90

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be 5.90%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±7.73% at a 95% confidence level.

AM COST ESTIMATOR

AM Cost Estimator is a system which predicts and/or estimates the time required to perform a variety of fabrication and assembly operations for numerous machines. In addition, selected manual operations can be developed by utilizing standard data elements. The estimated times were developed from time study, predetermined time systems, and other industrial data, or from a combination of the aforementioned methods. From these measurements, regression analysis was used to develop the AM Cost Estimator data.

In order to validate the accuracy of the system, the vendor provided a number of studies which compared times developed with the Cost Estimator system to actual time studies. A variety of machines were represented, including insertion machines, marking machine, injection molder, thermal deburrer, turret punch press, and CNC machines.

The study compared samples of AM Cost Estimator values to time study values. The average length of the operations studied was 1.96 min. for time study and 1.95 min. for AM Cost Estimator. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of AM Cost Estimator will not deviate greater than ±5% when compared to actual time study was tested (see Table 48).

A confidence level of 95% was used to obtain the critical region of $T < -2.021$ and $t > 2.021$, with 40 degrees of freedom.

Calculations for the "t" test statistic gave a value of -0.057, which fell within the range $-2.021 < t < 2.021$. Therefore, from the data provided, it can be concluded that, at the 95% confidence level, the accuracy of AM Cost Estimator is within the ±5% range.

TABLE 48
AM COST ESTIMATOR - "T" TEST

$H_0: \mu_D = d_0$

$H_1: \mu_D \neq d_0$

$\alpha = 0.05$ $\qquad \Sigma d = -0.149$

$\nu = 38$ $\qquad \Sigma d^2 = 6.56$

Critical Region

$T_{\alpha/2}: \quad T_{.025} < -2.021 \qquad T_{.025} > 2.021$

"t" test statistic

$$t = (\overline{D} - d_0)/S_d/\sqrt{n}$$

$$\overline{D} = \Sigma d/n = -0.149/39 = -0.0038$$

$$S_d^2 = (n\Sigma d^2 - (\Sigma d)^2)/n(n-1)$$

$$= (39(6.56) - (-0.149)^2)/39(38)$$

$$= 255.84 - .0222/39(38)$$

$$= 0.173$$

$$S_d = \sqrt{0.173} = 0.416$$

$$t = (-.0038 - 0)/.416/\sqrt{39}$$

$$= -0.057$$

$$-2.021 < -0.057 < 2.021$$

The values of the studies provided are shown in Table 49. The deviation and percent deviation for each study was calculated and summed.

Table 49

AM COST ESTIMATOR

ACTIVITY	TIME STUDY	AM COST ESTIMATOR	DEVIATION	% DEVIATION
1	.61	.51	-0.1	16.4
2	.62	.54	-0.08	12.90
3	1.38	1.69	0.31	22.46
4	1.50	1.90	0.4	26.67
5	3.15	3.11	-0.04	1.27
6	.182	.212	0.03	16.48
7	.108	.132	0.024	22.22
8	.145	.170	0.025	17.24
9	.114	.132	0.018	15.79
10	.102	.132	0.03	29.41
11	4.23	3.897	-0.333	7.87
12	4.13	4.297	0.167	4.04
13	5.35	5.361	0.011	.20
14	2.63	2.566	-0.064	2.43
15	2.74	2.966	0.226	8.25
16	1.185	1.196	0.011	.93
17	1.544	1.431	-0.113	7.32

ACTIVITY	TIME STUDY	AM COST ESTIMATOR	DEVIATION	% DEVIATION
18	2.216	2.224	0.008	.36
19	0.473	.465	-0.008	1.69
20	1.336	1.148	-0.188	14.1
21	4.87	4.56	-0.31	6.36
22	13.74	11.75	-1.99	14.48
23	3.07	4.28	1.21	39.41
24	6.53	7.12	0.59	9.04
25	2.64	2.86	0.22	8.33
26	8.05	7.73	-0.32	3.98
27	.011	.017	0.006	54.5
28	.034	.028	-0.006	17.65
29	.756	.785	0.029	3.84
30	.038	.038	0	0
31	.016	.020	0.004	25.00
32	.072	.107	0.035	48.61
33	.113	.176	0.063	55.75
34	.055	.071	0.016	29.09
35	.37	.45	0.08	21.62
36	.33	.25	-0.08	24.24
37	.62	.62	0	0
38	.64	.59	-0.05	7.81
39	.64	.66	0.02	3.12
TOTAL	76.34	76.191	-0.149	.20

CONCLUSION

Based on the above sample, the average deviation between the system and time study was found to be .20%.

WORK-FACTOR®

The **WORK-FACTOR®** system was developed and based on time studies.

Having gathered basic data for individual body motions required in manual work, the system was tested against actual operations, based on time studies, performed by a "statistically acceptable sample of experienced factory employees." From these time studies, data was plotted and smoothed into curves upon which formulas were derived.

Evaluation as to the accuracy of Work-Factor® was based on sample data provided by the system vendor. The studies provided were conducted by Phillips Electric of Holland, Sylvania Electric, and Aramco and SEB of West Germany. In the first study, 44 samples of Work-Factor® values were compared to MTM-1 values. The average length of the operations studied was 14 minutes for MTM-1 and 11.38 minutes for Work-Factor®. Using the student "t" test for match-pair observations, the hypothesis that the accuracy of Work-Factor® will not deviate greater than ±5% when compared to MTM-1 was tested (See Table 50.) A confidence level of 95% was used to obtain the critical region of $T < -2.021$ and $T > 2.021$, with 43 degrees of freedom.

Calculations for the "t" test statistic gave a value of -4.87, which did not fall within the range $-2.021 < t < 2.021$. Therefore, from the data provided in this study it can be concluded that the accuracy of Work-Factor® will deviate greater than ±5% at the 95% confidence level, when compared to MTM-1.

Table 50
Work-Factor® - "T" Test

$H_0: \mu_D = d_0$

$H_1: \mu_D \neq d_0$

$\alpha = .05$

$\nu = 43$

$\Sigma d = -115.56$

$\Sigma d^2 = 855.1658$

Critical region:

$T_{\alpha/2}$ $\quad T_{.025} < -2.021 \quad T_{.025} > 2.021$

"t" test statistic:

$$t = \overline{D} - d_0 / S_d/\sqrt{n}$$

$$\overline{D} = \Sigma d/n = -115.56/44 = -2.63$$

$$S_d^2 = (n\Sigma d^2 - (\Sigma d)^2) / n(n-1)$$

$$= (44(855.1658) - (-115.56)^2) / 44(43)$$

$$= (37,627.295 - 13,354.113) / 1,892$$

$$= 12.83$$

$$S_d = \sqrt{12.83} = 3.58$$

$$t = -2.63 - 0 / 3.58/\sqrt{44}$$

$$= -4.87$$

$$-2.021 \not< -4.87 < 2.021$$

The values of the studies provided are shown in Table 51. The deviation and percent deviation for each study was calculated and summed.

Table 51

Work-Factor® vs. MTM-1

ACTIVITY	MTM-1	WORK-FACTOR®	DEVIATION	% DEVIATION
1	2.84	2.08	-0.76	-26.8
2	2.65	1.87	-0.78	-29.4
3	2.56	2.00	-0.56	-21.9
4	3.15	2.33	-0.82	-26.0
5	2.81	2.16	-0.65	-23.1
6	3.69	2.39	-1.3	-35.2
7	3.52	2.25	-1.27	-36.1

ACTIVITY	MTM-1	WORK-FACTOR®	DEVIATION	% DEVIATION
8	3.64	2.77	-0.87	-23.9
9	3.52	2.14	-1.38	-39.2
10	2.70	1.87	-0.83	-30.7
11	3.52	2.47	-1.05	-29.8
12	3.26	2.60	-0.66	-20.2
13	2.96	2.35	-0.61	-20.6
14	3.26	2.24	-1.02	-31.3
15	3.09	2.13	-0.96	-31.1
16	3.26	2.24	-1.02	-31.3
17	3.26	2.46	-0.8	-24.5
18	3.67	2.42	-1.25	-34.1
19	3.26	2.35	-0.91	-27.9
20	3.32	2.34	-0.98	-29.5
21	2.07	1.85	-0.22	-10.6
22	1.91	1.54	-0.37	-19.4
23	3.58	3.20	-0.38	-10.6
24	2.16	1.60	-0.56	-25.9
25	1.88	1.73	-0.15	-8.0
26	1.73	1.75	+0.02	+1.2
27	1.97	1.76	-0.21	-10.7
28	2.01	1.71	-0.3	-14.9
29	3.58	3.08	-0.5	-14.0
30	53.44	44.54	-8.9	-16.7
31	29.90	24.43	-5.47	-18.3
32	27.80	23.97	-3.83	-13.8
33	50.69	40.72	-9.97	-19.7
34	63.80	53.73	-10.07	-15.8
35	45.30	37.94	-7.36	-16.2
36	39.56	33.24	-6.32	-16.0
37	9.30	6.88	-2.42	-26.0
38	5.10	4.00	-1.1	-21.6
39	9.40	8.20	-1.2	-12.8
40	20.35	17.08	-3.27	-16.1

ACTIVITY	MTM-1	WORK-FACTOR®	DEVIATION	% DEVIATION
41	28.58	26.37	-2.21	-7.7
42	52.90	40.18	-12.72	-24.0
43	27.51	22.19	-5.32	-19.3
44	67.76	53.51	-14.25	-21.0
TOTAL	616.22	500.66	-115.56	18.75

CONCLUSION

Based on the above sample, the average deviation between the two systems was found to be 18.75%. Based on the Accumulated System Accuracy formula, such a deviation will reflect an overall system accuracy of ±19.4%.

In a second study, the same 44 samples of Work-Factor® values were compared to time study values. The average length of the operations studied was 14.13 minutes for time study and 11.38 minutes for Work-Factor®. Using the student "t" test for matched-pair observations, the hypothesis that the accuracy of Work-Factor® will not deviate greater than ±5% when compared to time study was tested. (See Table 52.) A confidence level of 95% was used to obtain the critical region of $T < -2.021$ and $T > 2.021$, with 43 degrees of freedom.

Calculations for the "t" test statistic gave a value of -4.33, which did not fall within the range $-2.021 < t < 2.021$. Therefore, from the data provided in this study, it can be concluded that the accuracy of Work-Factor® will deviate greater than ±5% at the 95% confidence level, when compared to time study.

Table 52
Work-Factor® - "T" Test

H_0: $\mu_D = d_0$

H_1: $\mu_D \neq d_0$

$\alpha = 0.05$

$\nu = 43$

$\Sigma d = -121.06$

$\Sigma d^2 = 1094.72$

Critical region:

$T_{\alpha/2}$ $T_{.025} < -2.021$ $T_{.025} > 2.021$

"t" test statistic:

$$t = \overline{D} - d_0 \;/\; S_d/\sqrt{n}$$

$$\overline{D} = \sum d/n = -121.06/44 = -2.75$$

$$S_d^2 = n\sum d^2 - (\sum d)^2 \;/\; n(n-1)$$

$$= 44(1094.72) - (-121.06)^2 \;/\; 44(43)$$

$$= 17.71$$

$$S_d = \sqrt{17.71} = 4.21$$

$$t = -2.75 - 0 \;/\; 4.21/\sqrt{44}$$

$$= -4.33$$

The values of the studies provided are shown in Table 53. The deviation and percent deviation for each study was calculated and summed.

Table 53

Work-Factor® vs. Time Study

ACTIVITY	MTM-1	WORK-FACTOR®	DEVIATION	% DEVIATION
1	2.44	2.08	-0.36	-14.75
2	2.08	1.87	-0.21	-10.1
3	2.30	2.00	-0.3	-13.0
4	2.64	2.33	-0.31	-11.7
5	2.64	2.16	-0.48	-18.2
6	2.63	2.39	-0.24	-9.1
7	2.64	2.25	-0.39	-14.8

ACTIVITY	MTM-1	WORK-FACTOR®	DEVIATION	% DEVIATION
8	3.22	2.77	-0.45	-14.0
9	2.81	2.14	-0.67	-23.8
10	2.17	1.87	-0.3	-13.8
11	2.75	2.47	-0.28	-10.2
12	2.94	2.60	-0.34	-11.6
13	2.90	2.35	-0.55	-19.0
14	2.70	2.24	-0.46	-17.0
15	2.75	2.13	-0.62	-22.5
16	2.75	2.24	-0.51	-18.5
17	3.15	2.46	-0.69	-21.9
18	2.80	2.42	-0.38	-13.6
19	2.90	2.35	-0.55	-19.0
20	2.80	2.34	-0.46	-16.4
21	2.36	1.85	-0.51	-21.6
22	2.08	1.54	-0.54	-26.0
23	4.05	3.20	-0.85	-21.0
24	1.80	1.60	-0.2	-11.1
25	1.90	1.73	-0.17	-8.9
26	2.00	1.75	-0.25	-12.5
27	2.15	1.76	-0.39	-18.1
28	2.25	1.71	-0.54	-24.0
29	3.82	3.08	-0.74	-19.4
30	51.90	44.54	-7.36	-14.2
31	29.70	24.43	-5.27	-17.7
32	28.90	23.97	-4.93	-17.1
33	53.70	40.72	-12.98	-24.2
34	70.70	53.73	-16.97	-24.0
35	49.70	37.94	-11.76	-23.7
36	40.90	33.24	-7.66	-18.7
37	7.60	6.88	-0.72	-9.5
38	5.10	4.00	-1.1	-21.6
39	9.00	8.20	-0.8	-8.9
40	22.50	17.08	-5.42	-24.1

ACTIVITY	MTM-1	WORK-FACTOR®	DEVIATION	% DEVIATION
41	32.50	26.37	-6.13	-18.9
42	50.60	40.18	-10.42	-20.6
43	28.40	22.19	-6.21	-21.9
44	64.10	53.51	-10.59	-16.5
TOTAL	621.72	500.66	-121.06	19.47

Based on the above sample, the average deviation between the two systems was found to be 19.47%.

CONCLUSION

Based on the evaluation of the two studies provided, it was apparent that standards developed by using Work-Factor® were consistently tighter than standards developed by either MTM-1 or Time Study. The system was so consistent that percent deviations were almost identical. To substantiate this apparent system bias to underestimate the standard time, system users were contacted and questioned as to their experience in applying the system. Based on these discussions, it was determined that, during actual application, the standards developed reflect a performance level of an average experienced operator working at an above-normal pace, which may answer the question as to why the bias is experienced.

Although the studies provided did not enable the verification, beyond doubt, of the system's accuracy and ability to meet MIL STD 1567A requirements, it is believed that the system can meet MIL STD 1567A requirements if leveling techniques are properly applied. Such leveling is consistent with the MIL STD and if documented and used properly will enable system bias to be controlled.

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